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(54) **CO-LOCATED GIMBAL-BASED DUAL STAGE ACTUATION DISK DRIVE SUSPENSIONS WITH MOTOR STIFFENERS**

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CPC ***G11B 5/4833*** (2013.01); ***G11B 5/483*** (2015.09); ***G11B 5/4826*** (2013.01); ***G11B 5/4873*** (2013.01)

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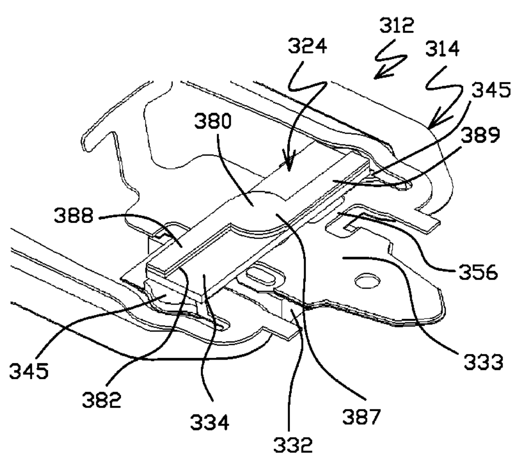
(57) **ABSTRACT**

Various embodiments concern a gimbaled flexure having a dual stage actuation structure. The flexure comprises a gimbal which includes a pair of spring arms, a pair of struts, and a tongue between the spring arms. A motor is mounted on the gimbal. The motor comprises a top side and a bottom side opposite the top side. The bottom side of the motor faces the flexure. A stiffener is mounted on the top side of the motor. At least one layer of adhesive is located between the stiffener and the motor and bonded to the stiffener and the motor. The gimbaled flexure includes a slider mounting for attaching a slider, such as to the tongue. The motor bends the struts to move the slider mounting about a tracking axis while the stiffener limits the degree of bending of the motor.

17 Claims, 51 Drawing Sheets



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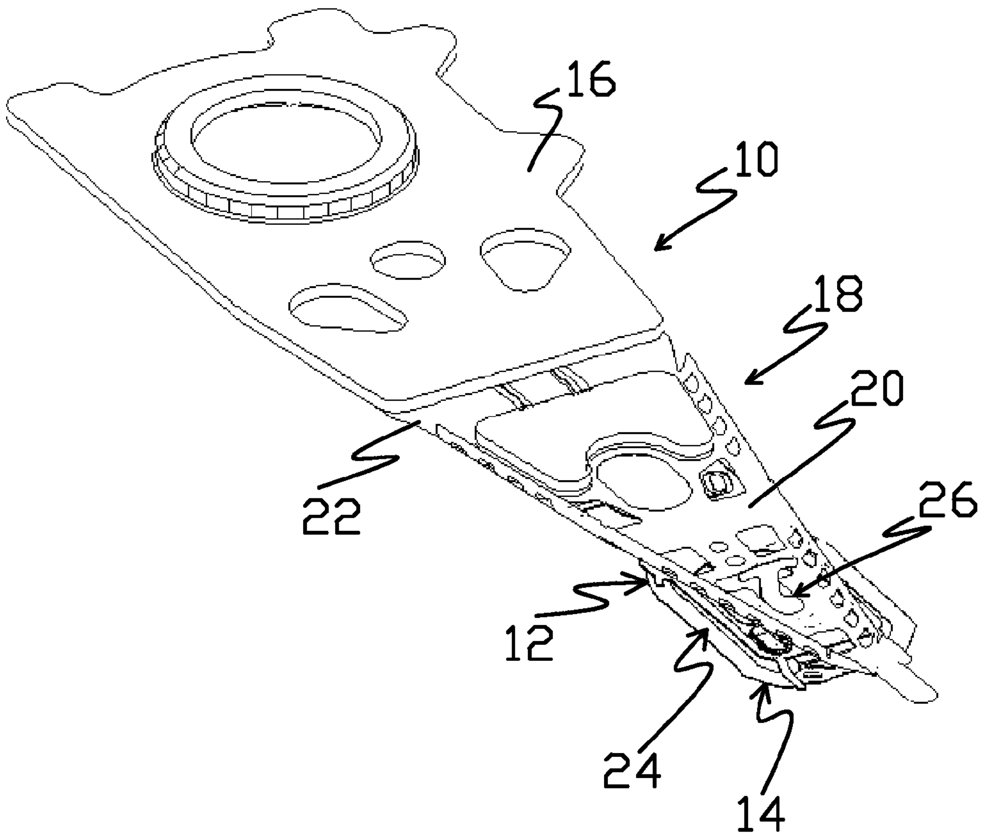


FIG 1

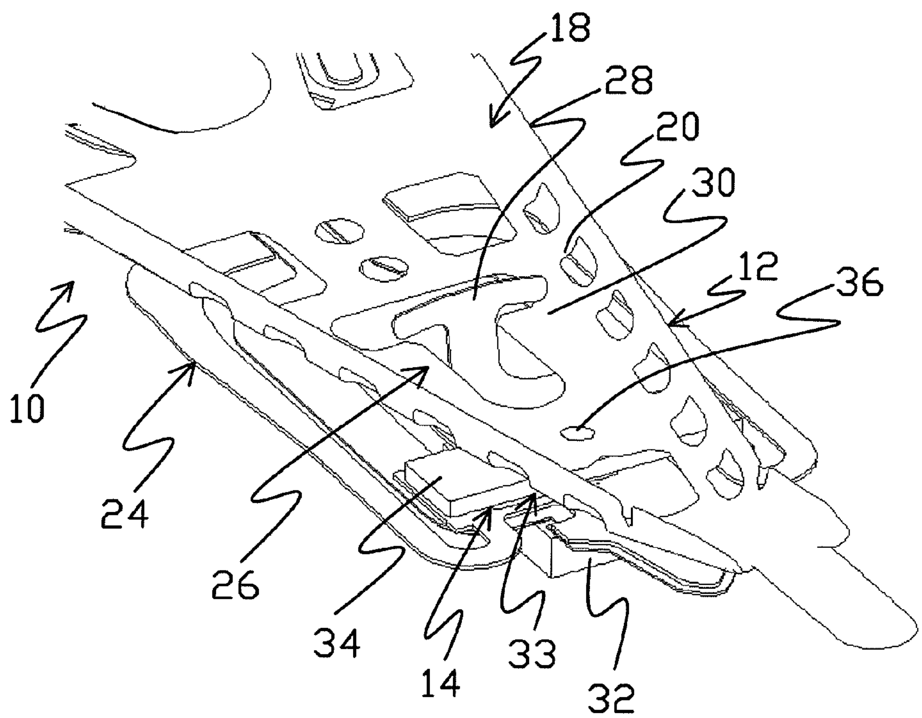


FIG 2

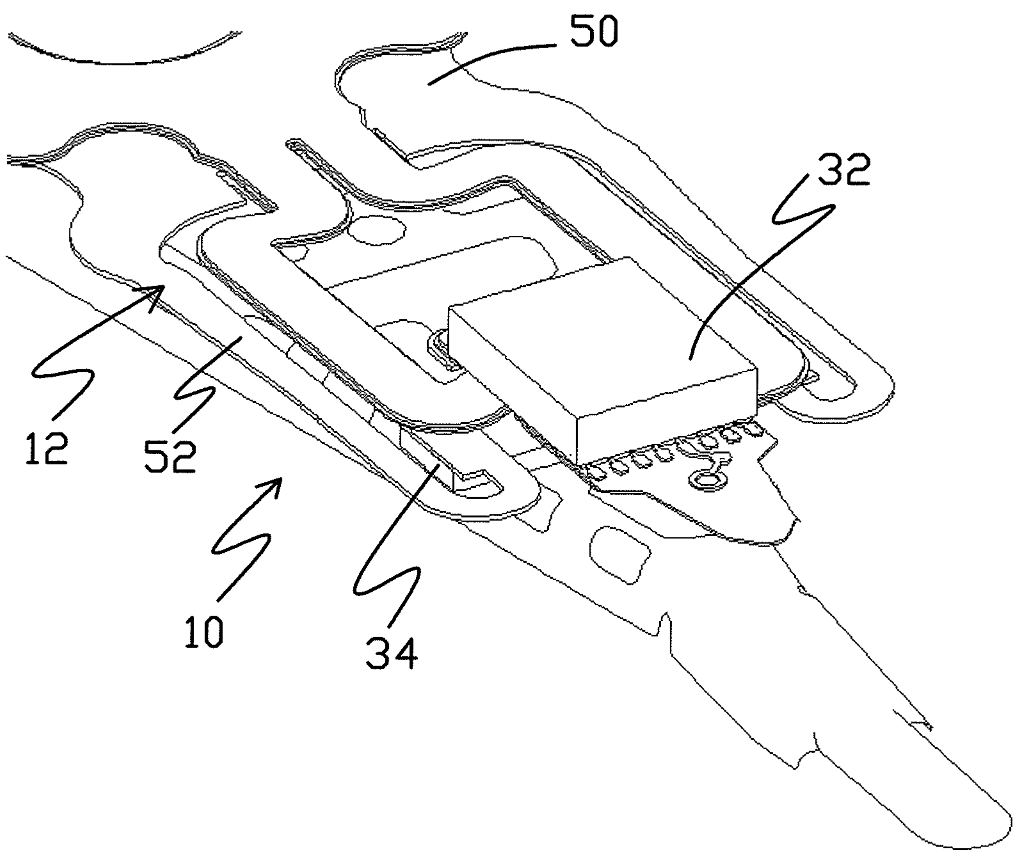


FIG 3

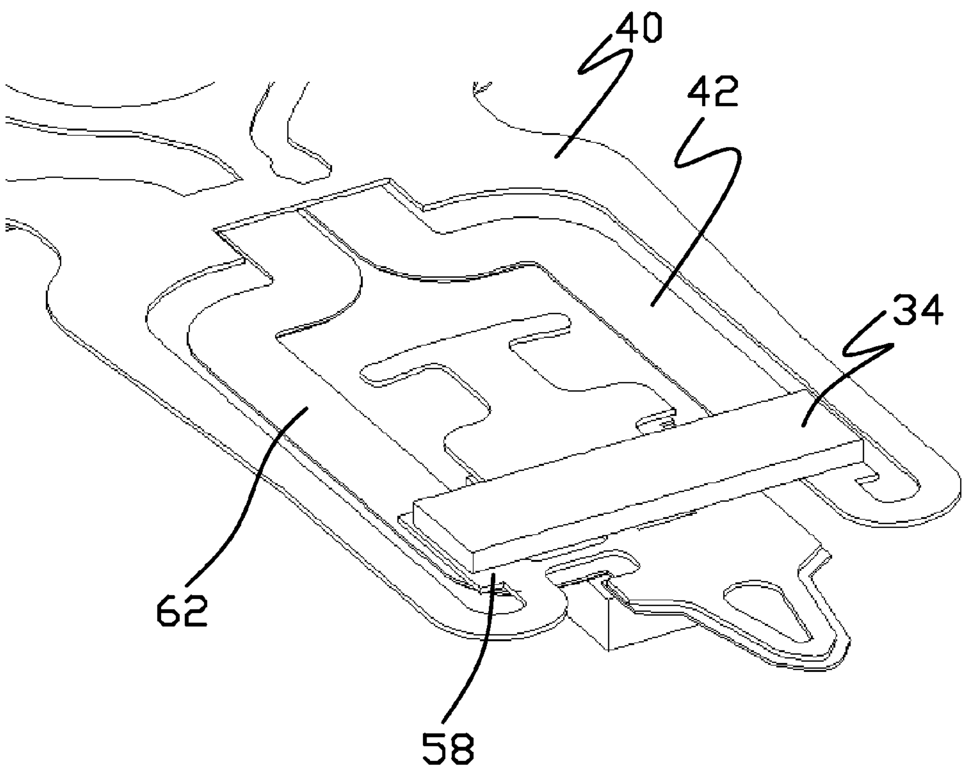


FIG 4A

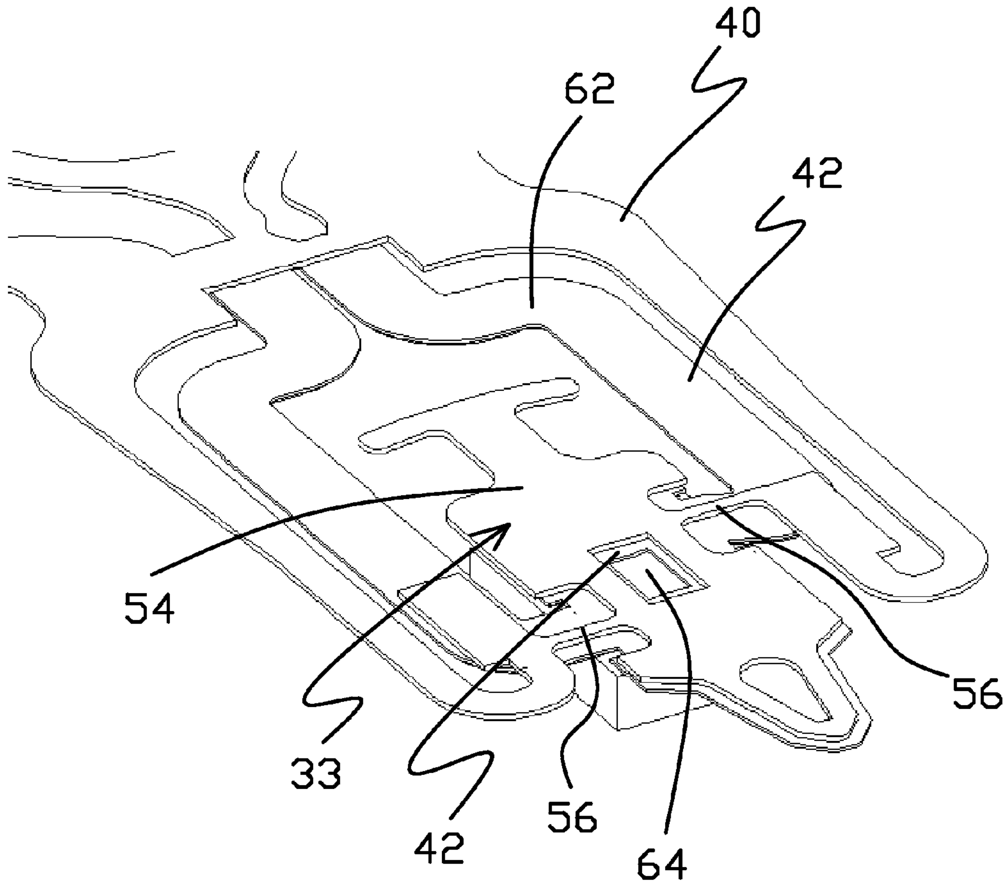


FIG 4B

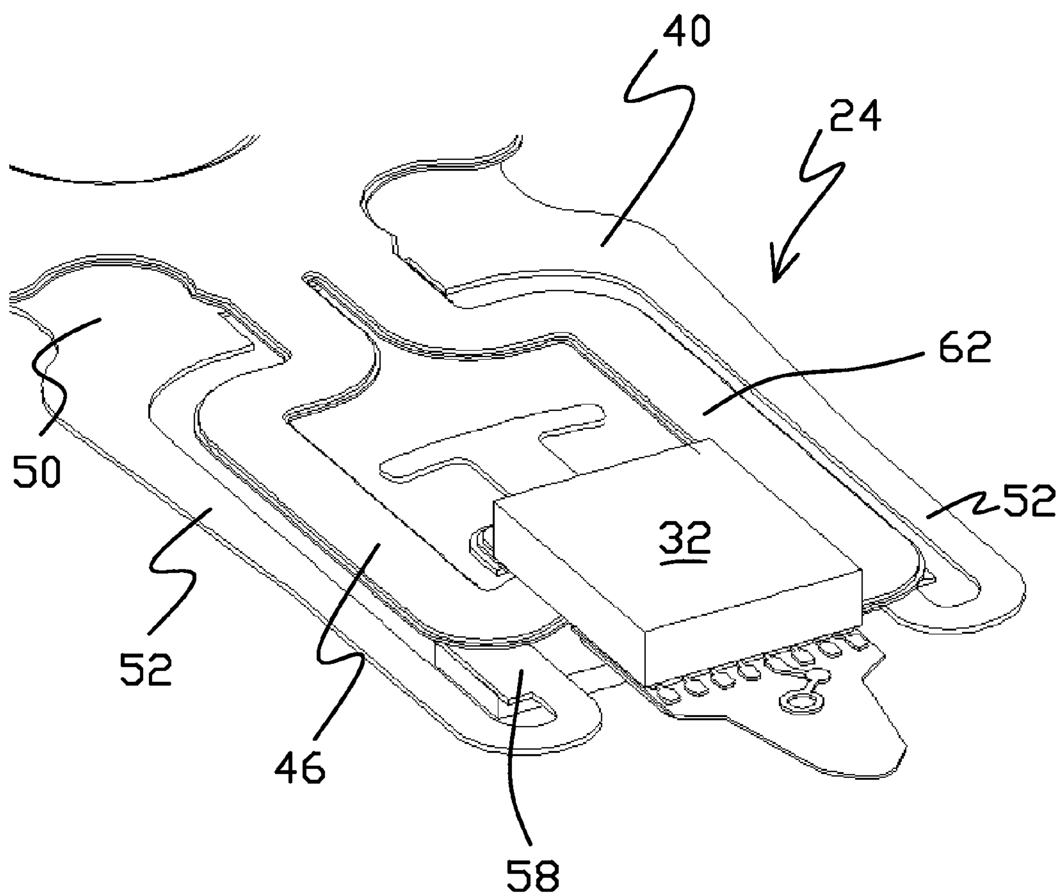


FIG 5A

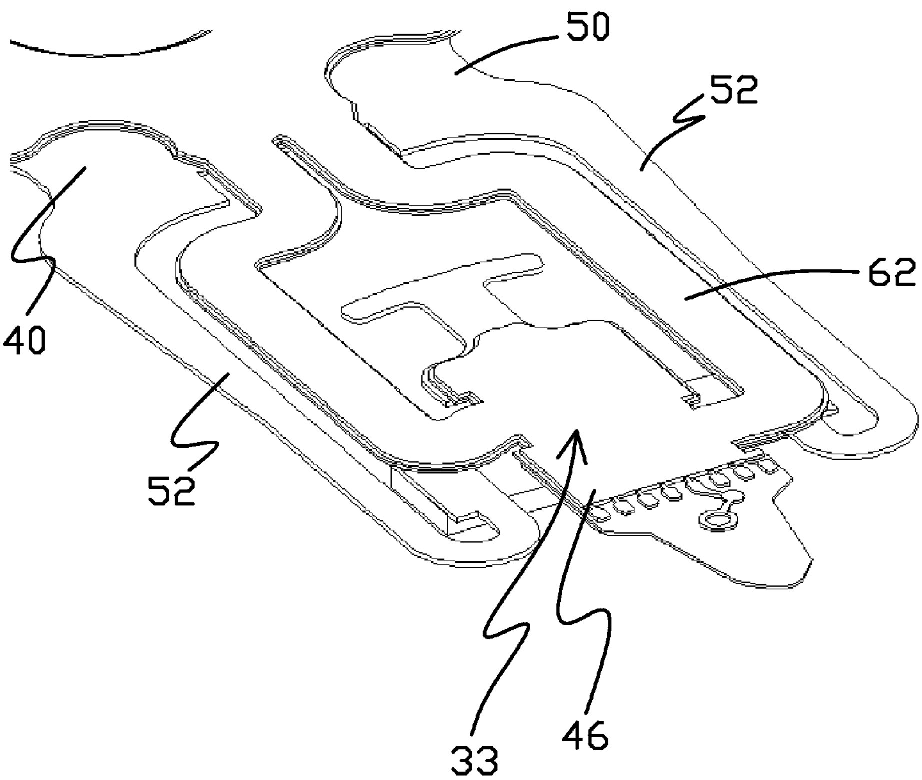


FIG 5B

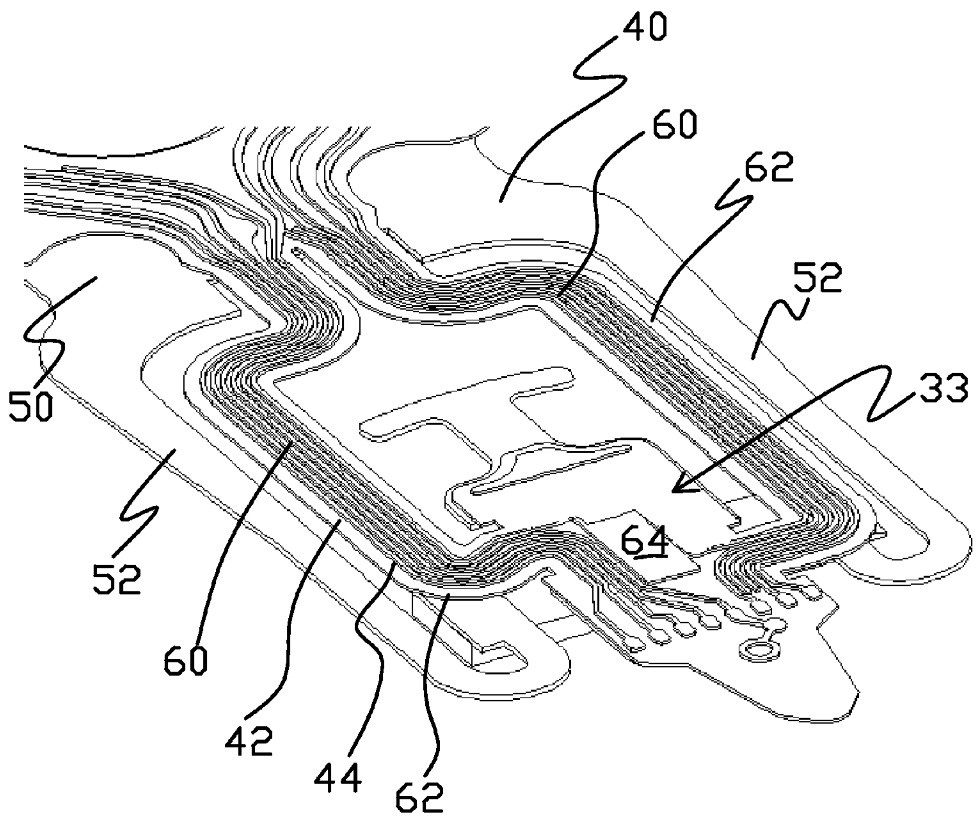


FIG 5C

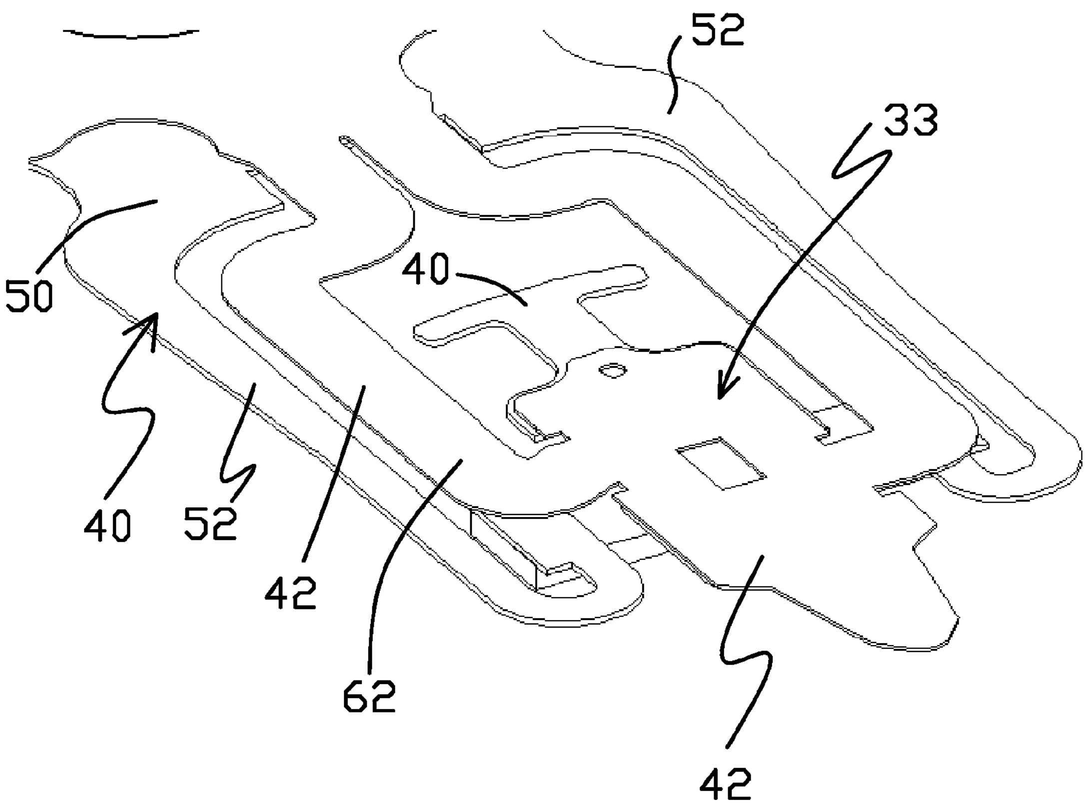


FIG 5D

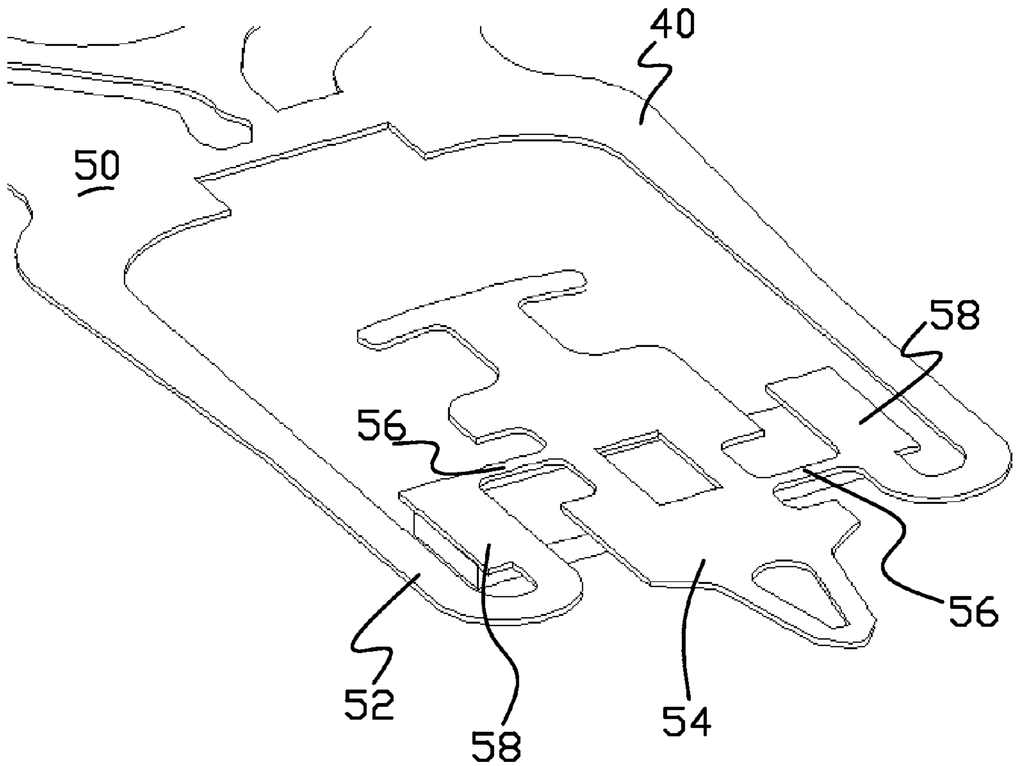


FIG 5E

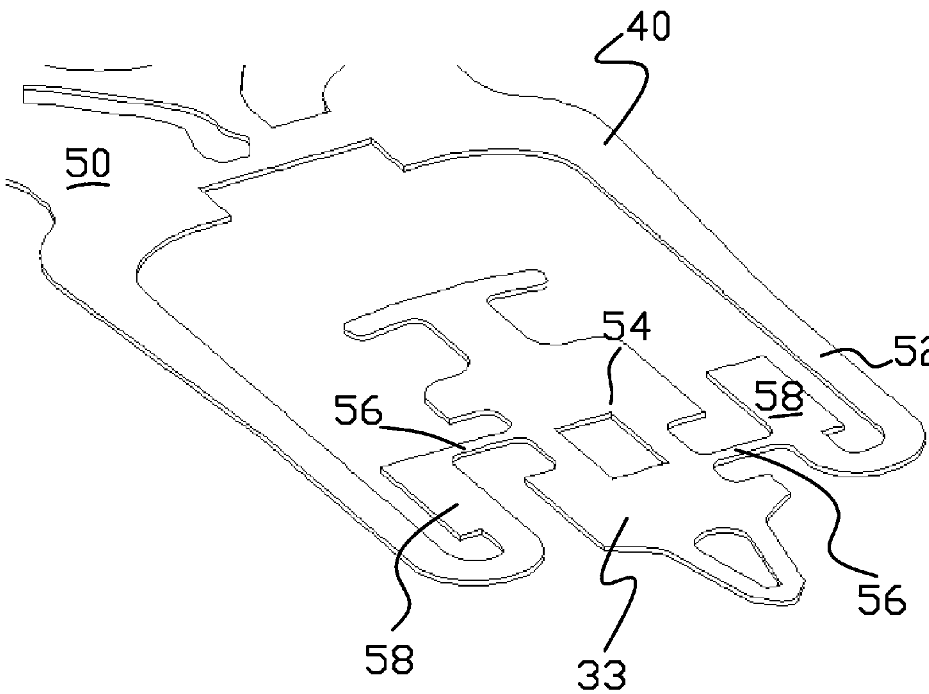


FIG 5F

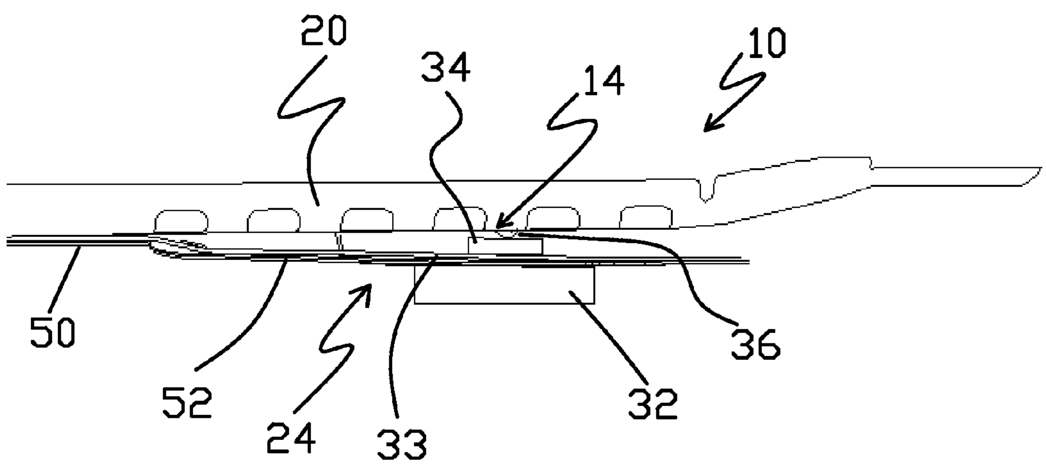


FIG 6

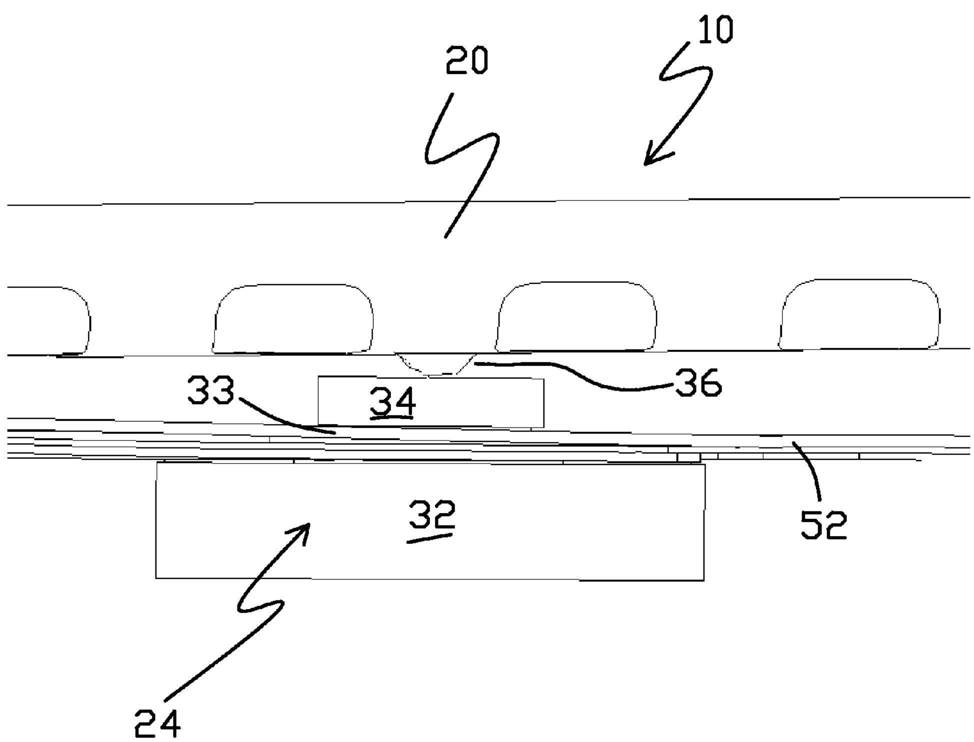


FIG 7

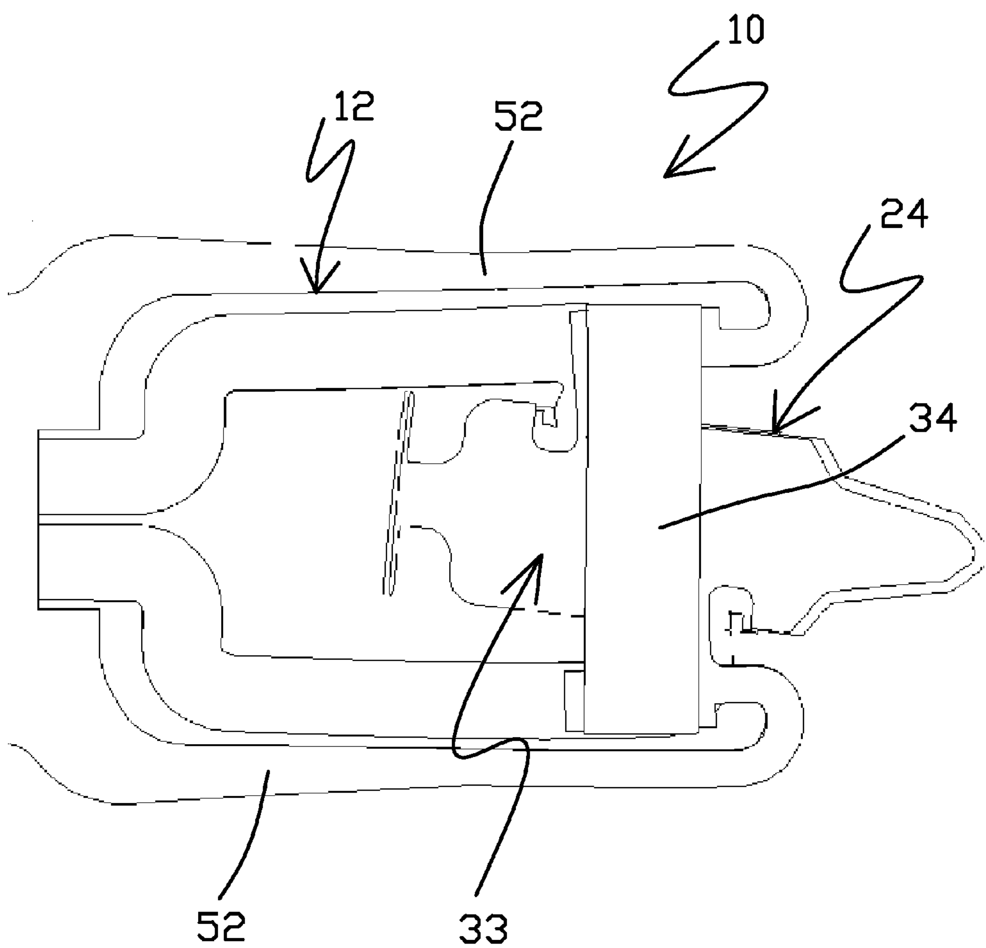
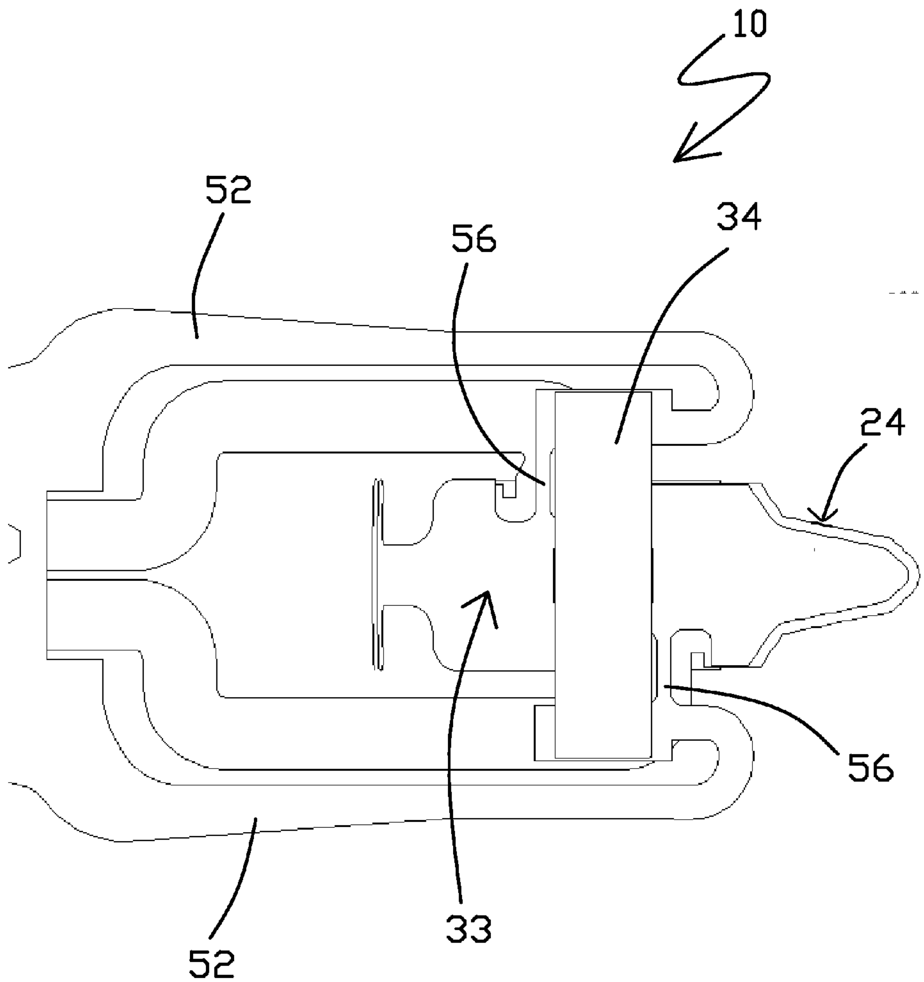


FIG 8A



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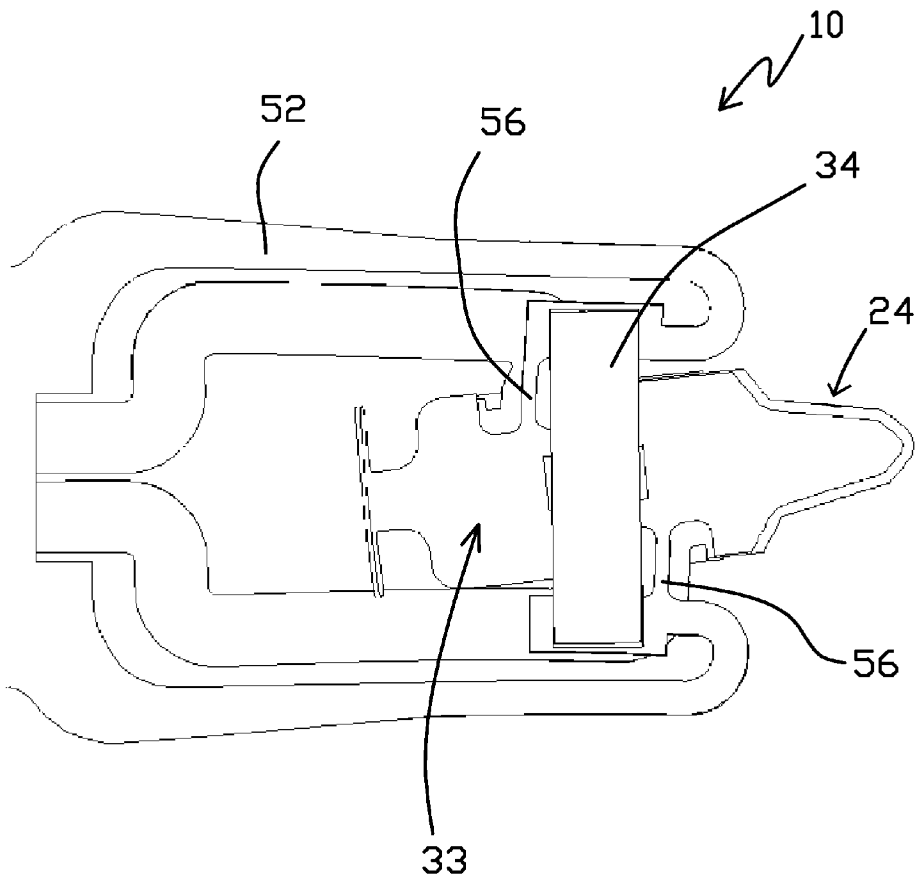

FIG 8C

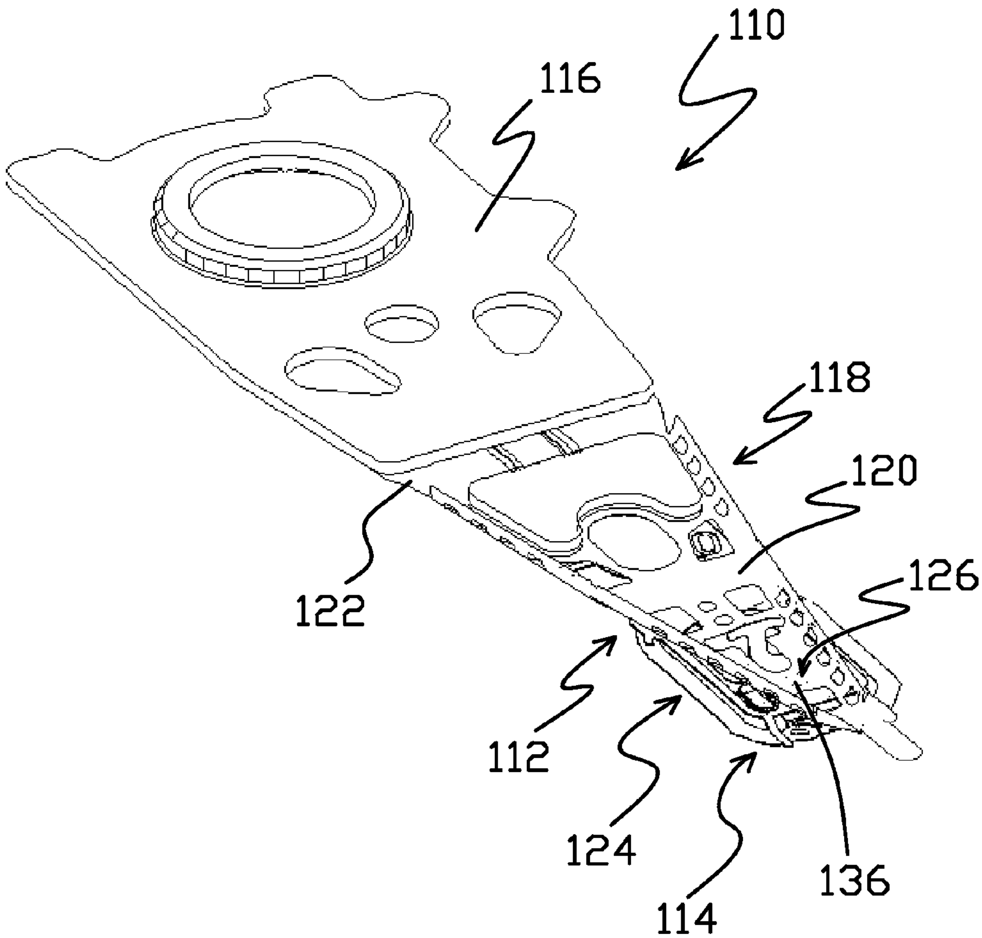

FIG 9

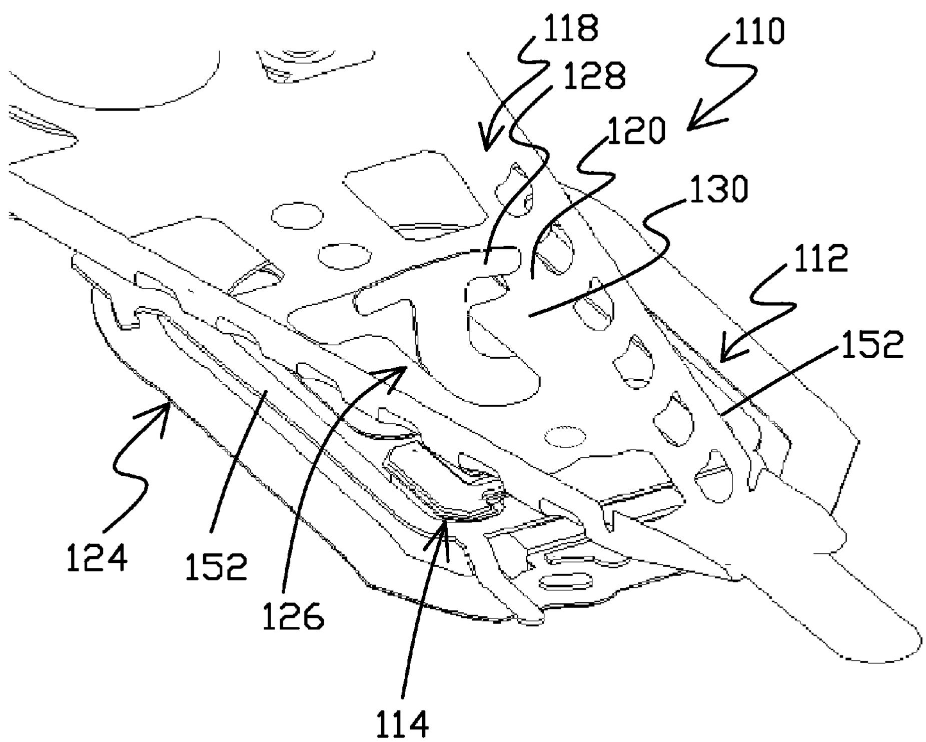

FIG 10

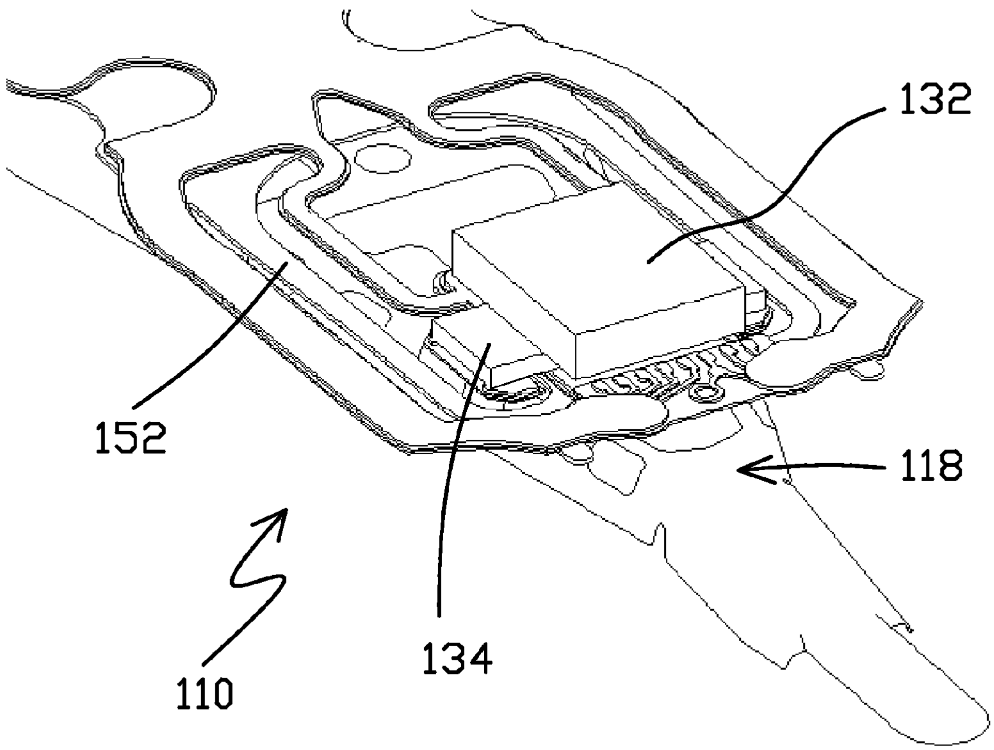

FIG 11

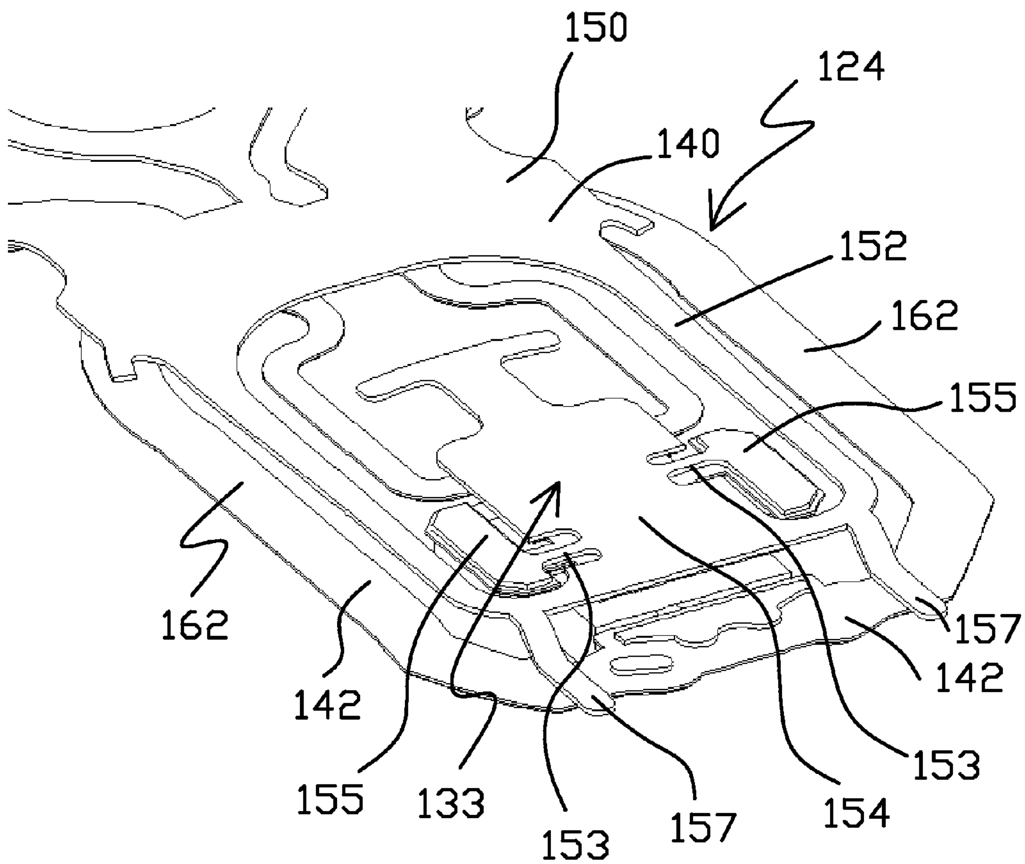

FIG 12

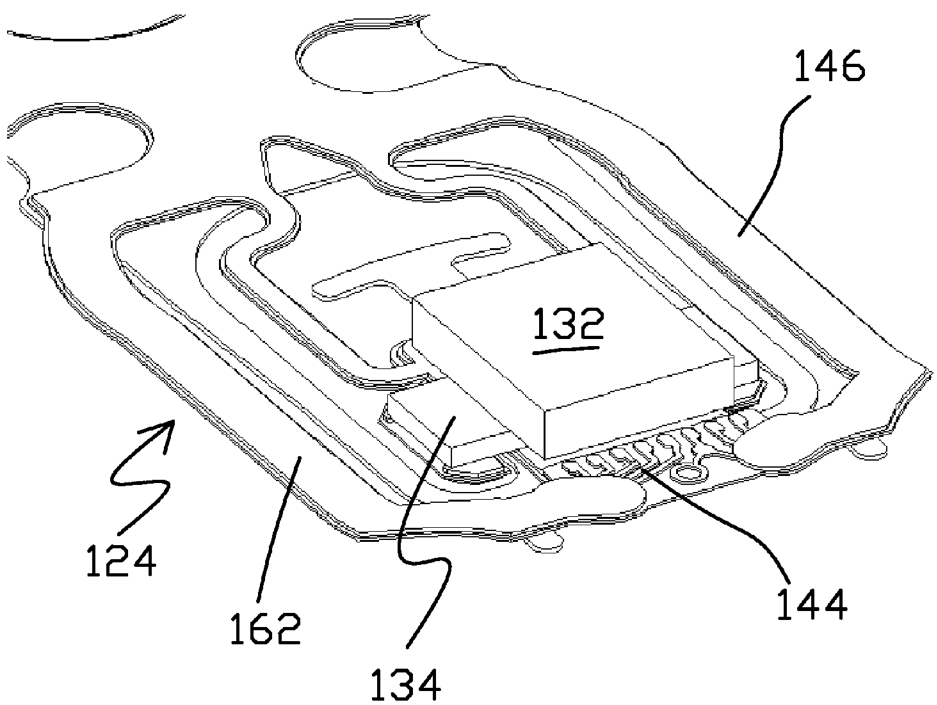

FIG 13A

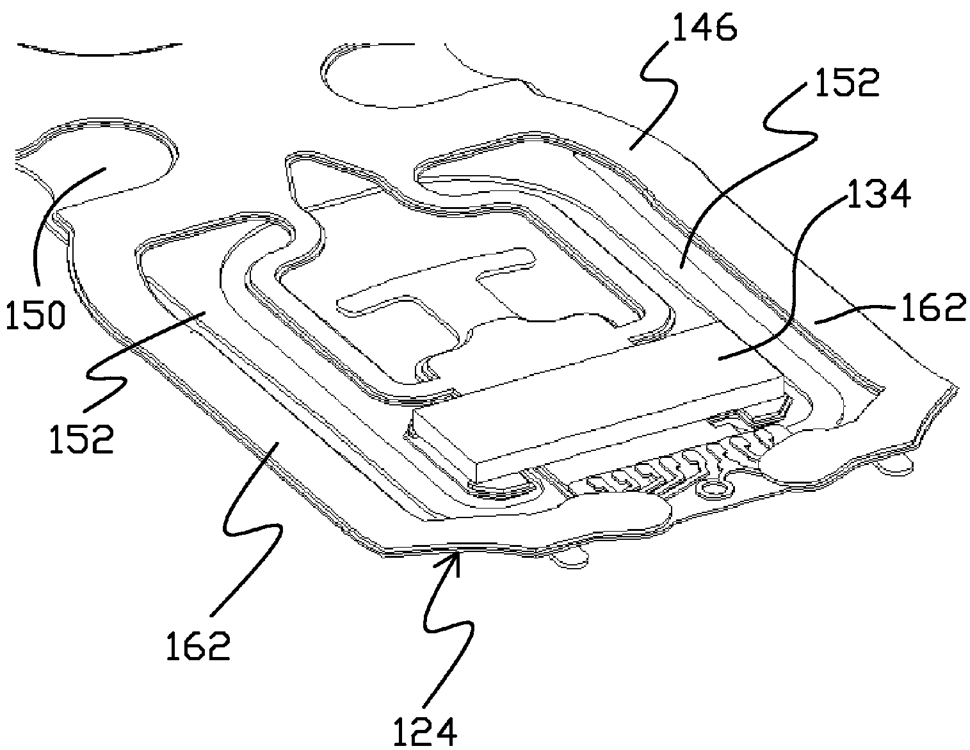

FIG 13B

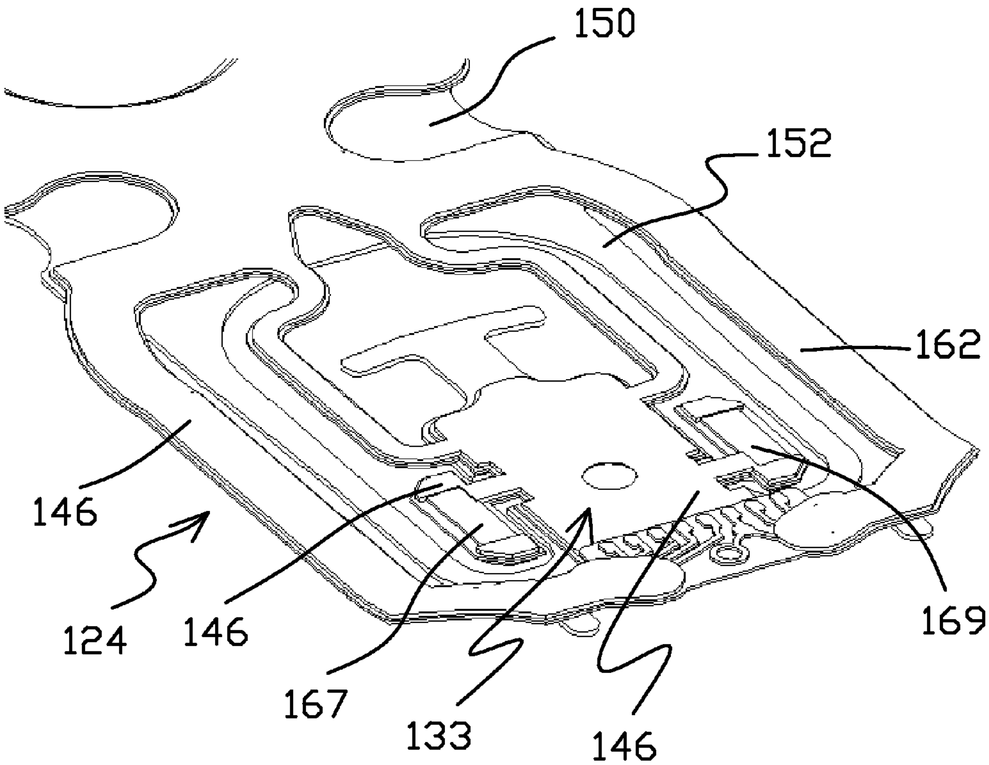

FIG 13C

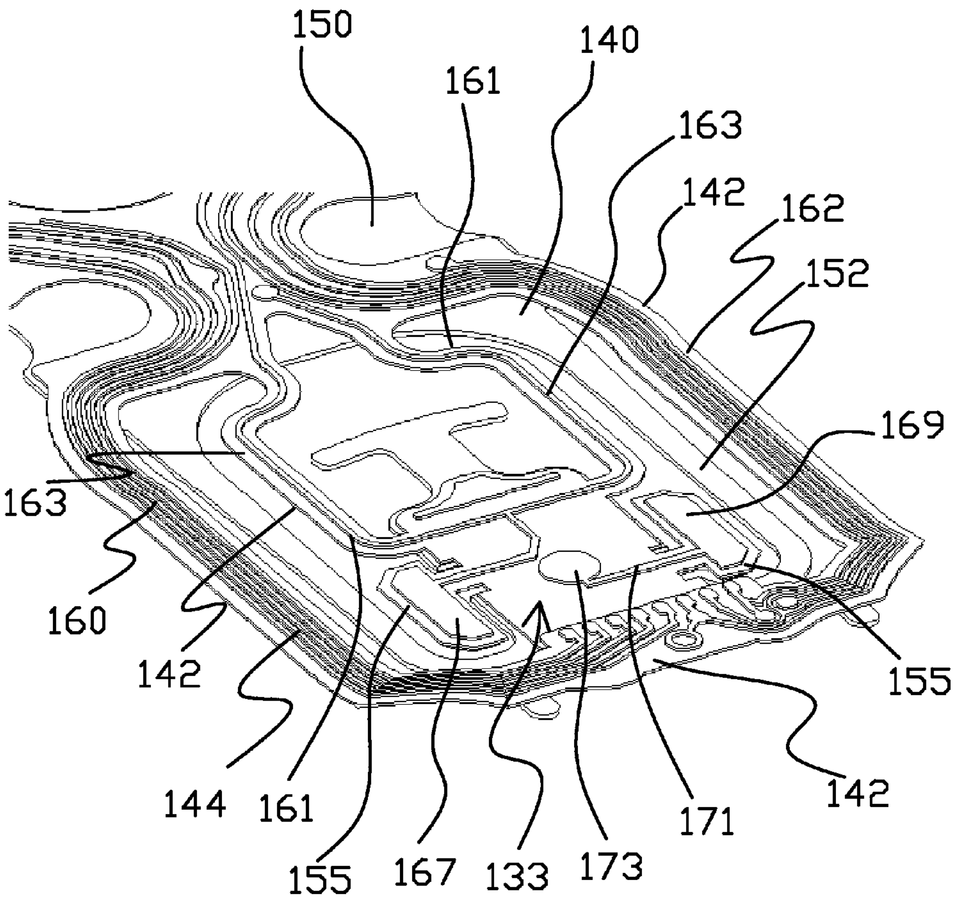
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FIG 13D

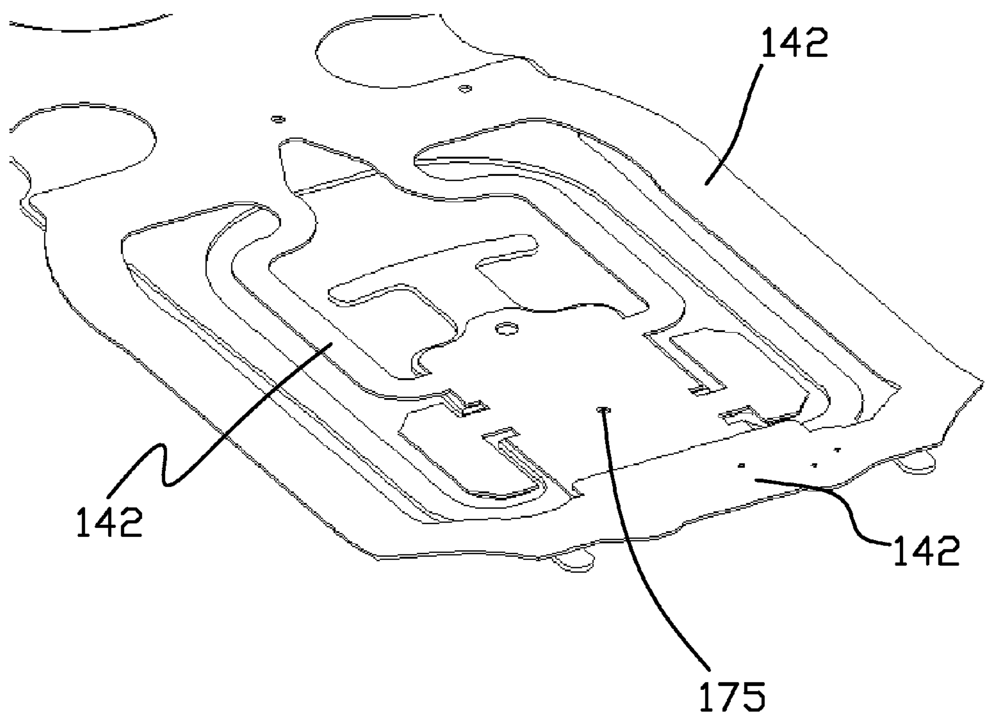


FIG 13E

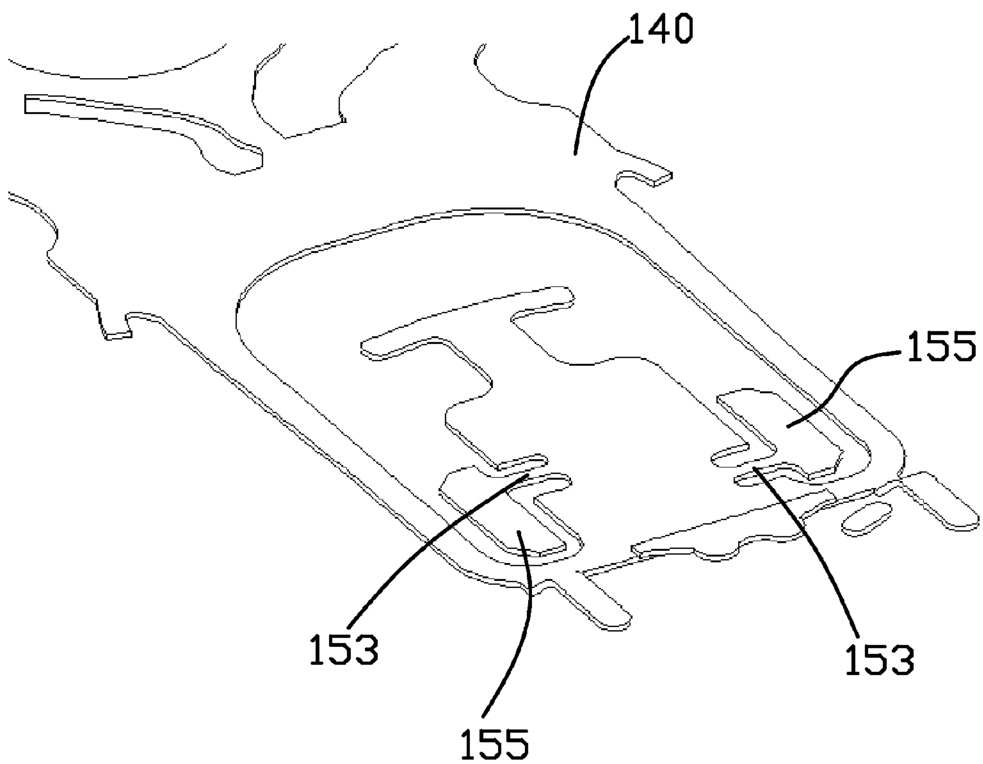


FIG 13F

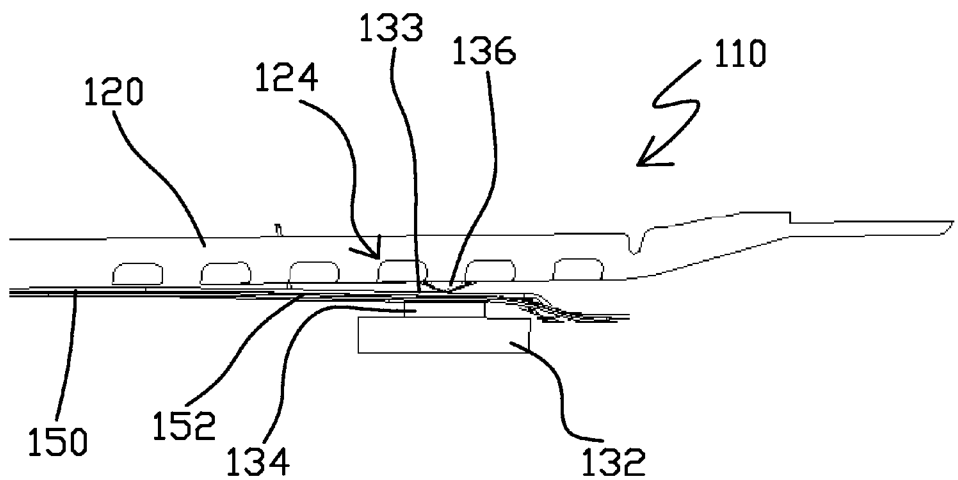


FIG 14

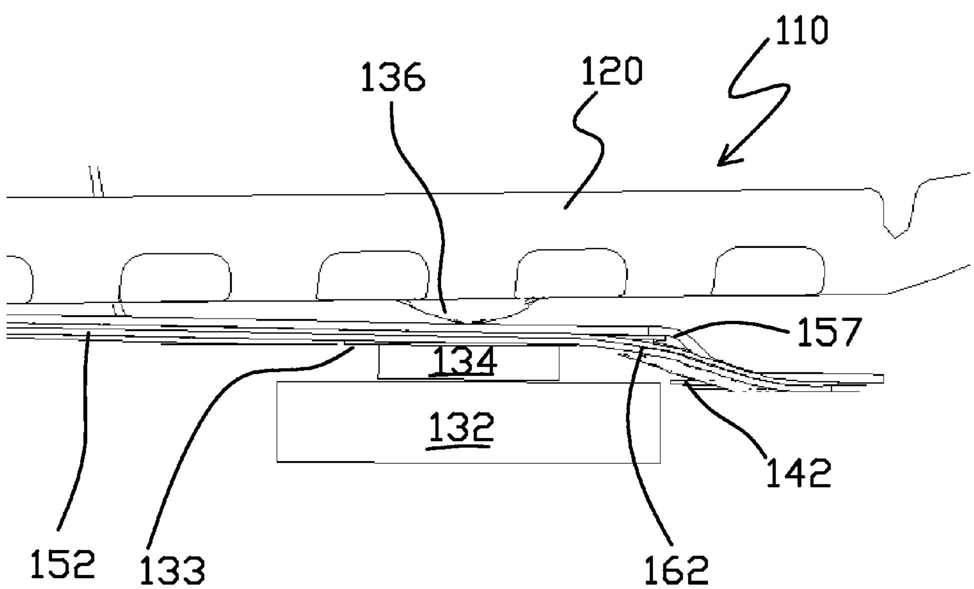


FIG 15

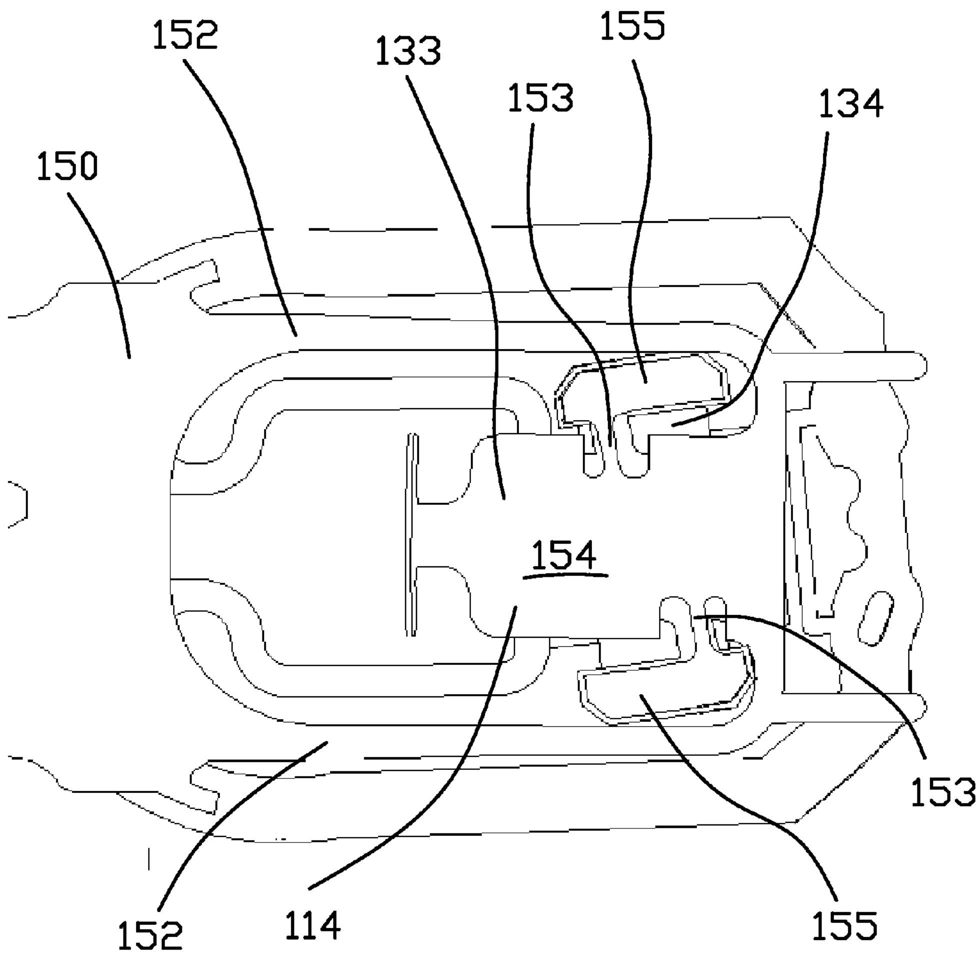


FIG 16A1

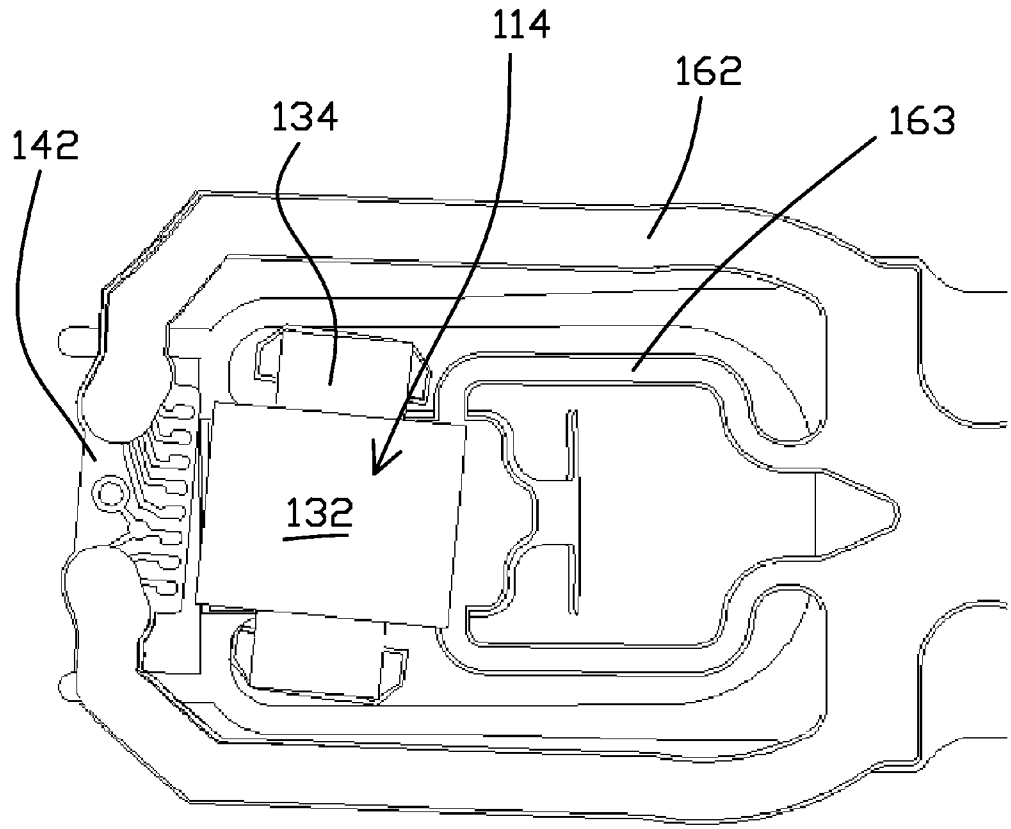


FIG 16A2

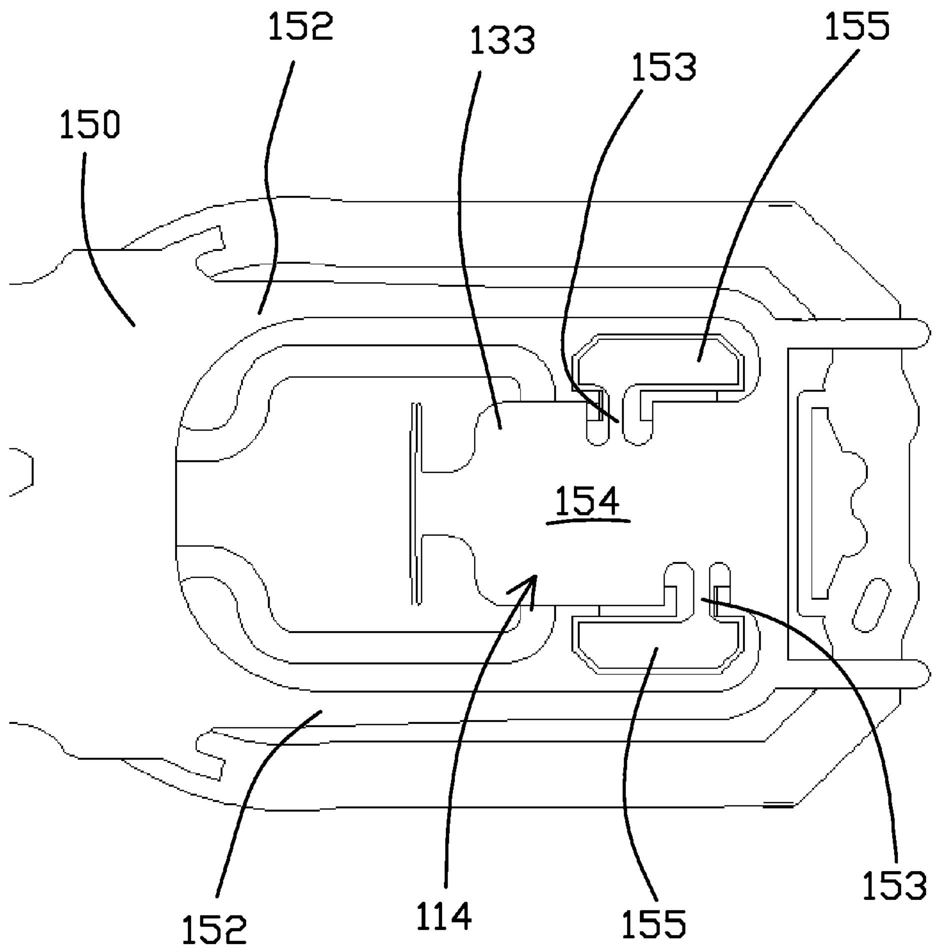
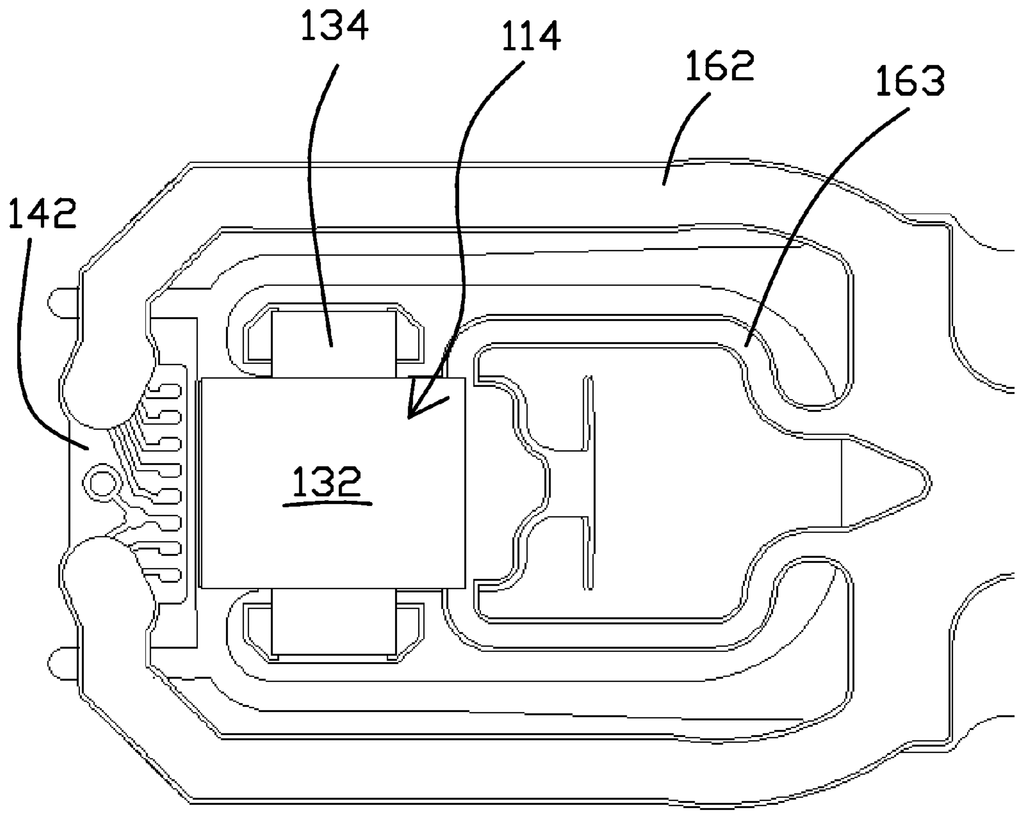


FIG 16B1



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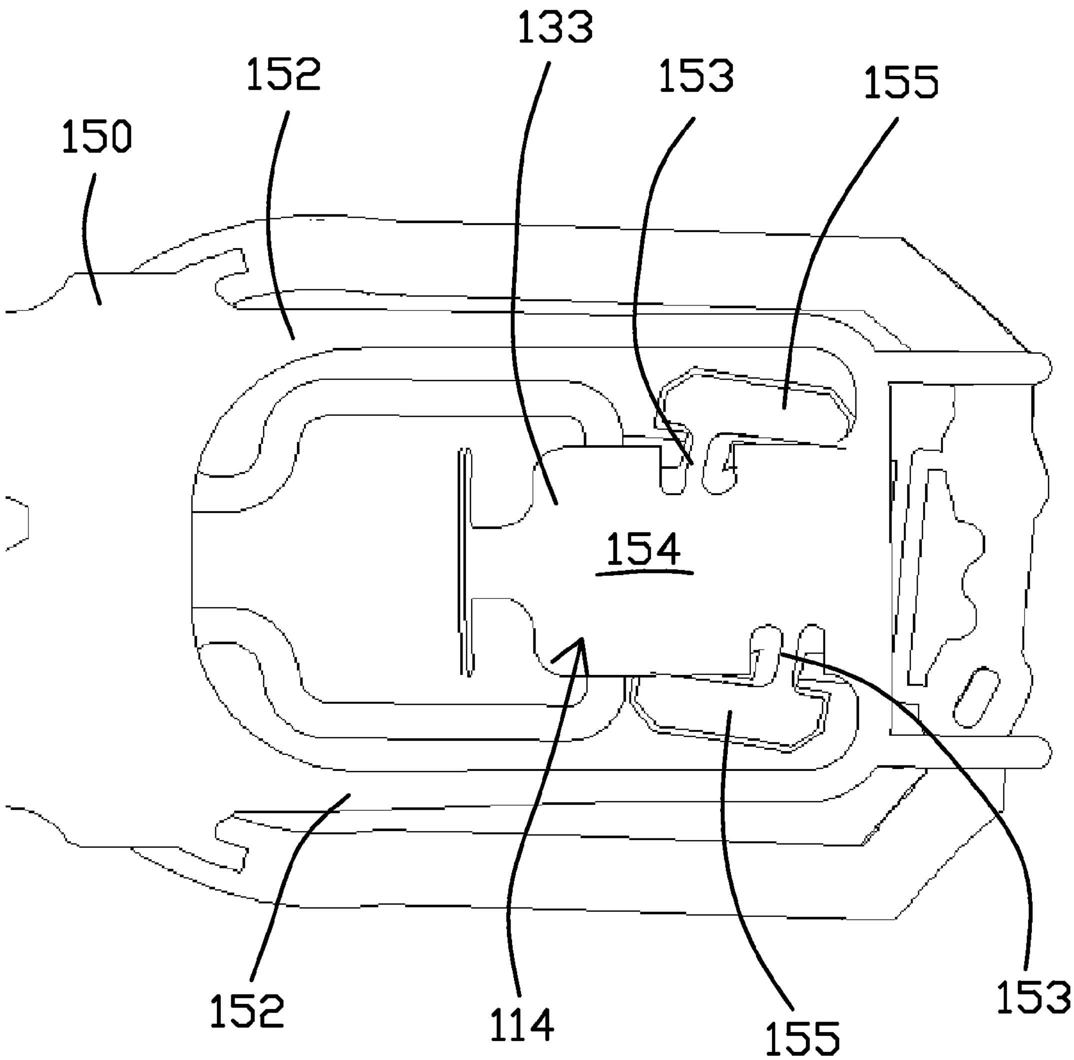

FIG 16C1

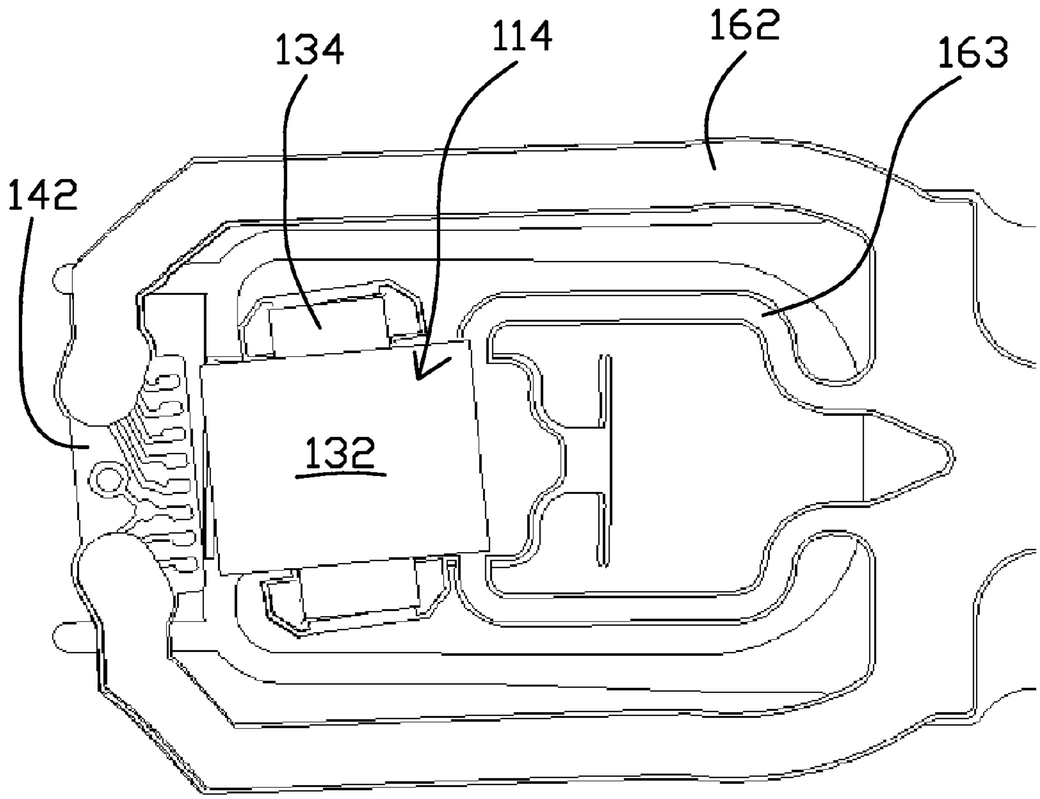

FIG 16C2

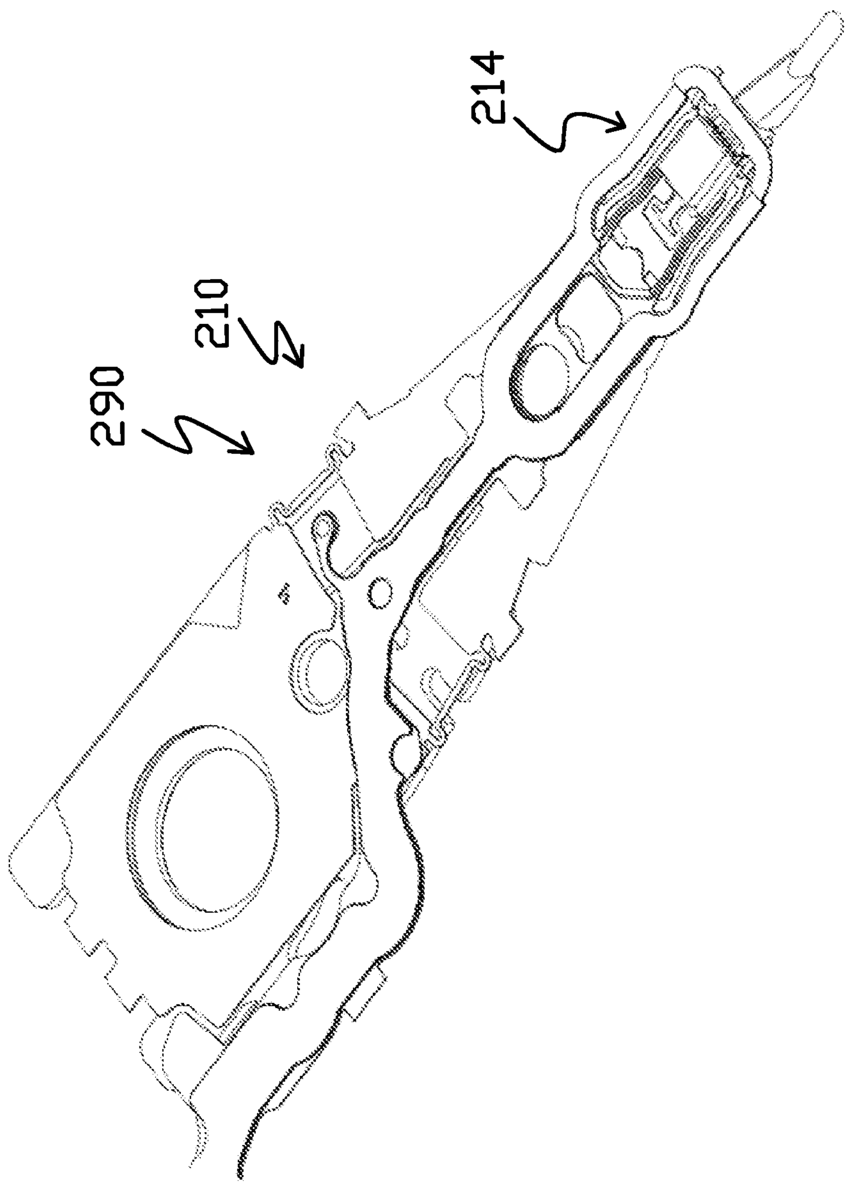

FIG 17

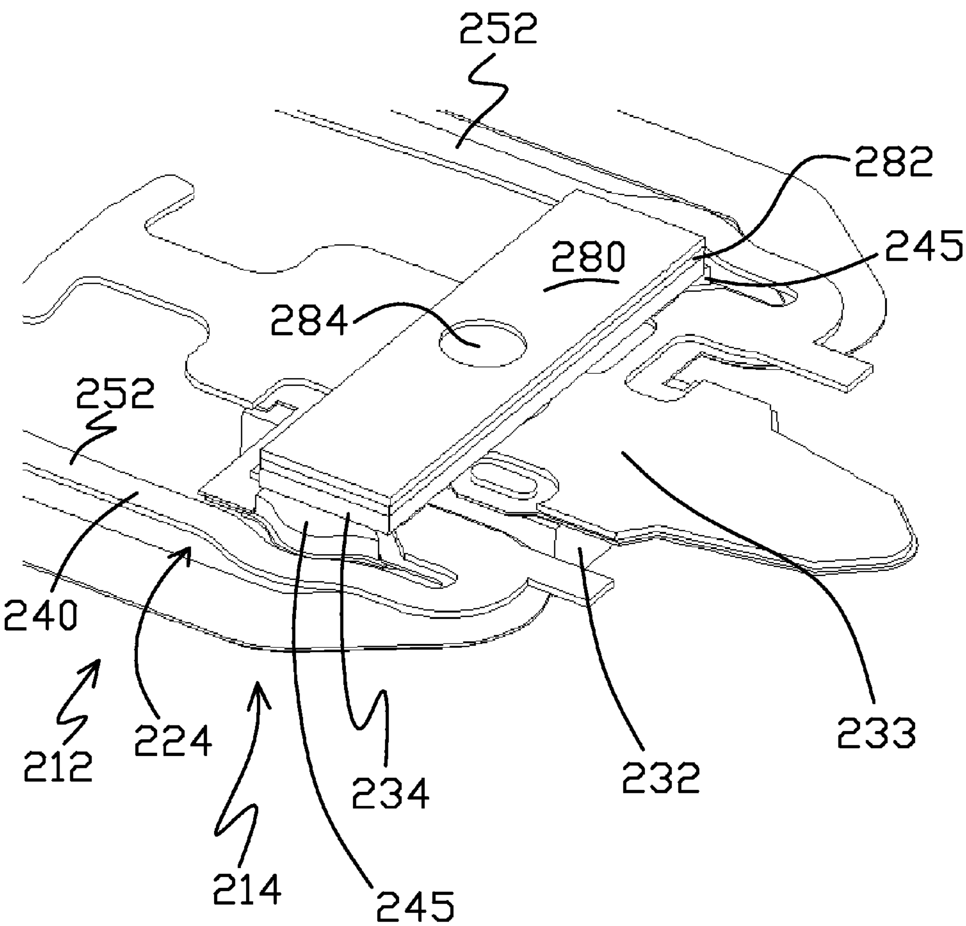

FIG 18

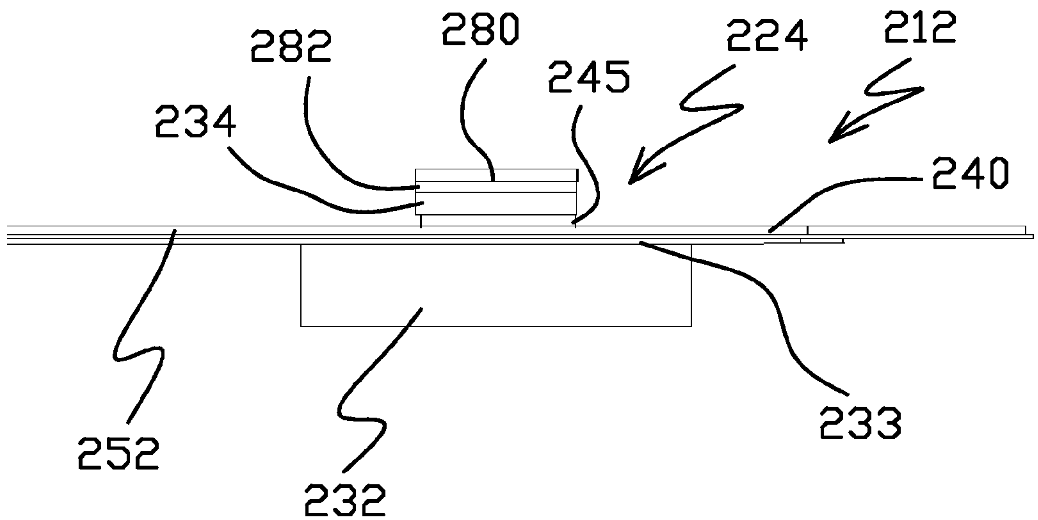

FIG 19

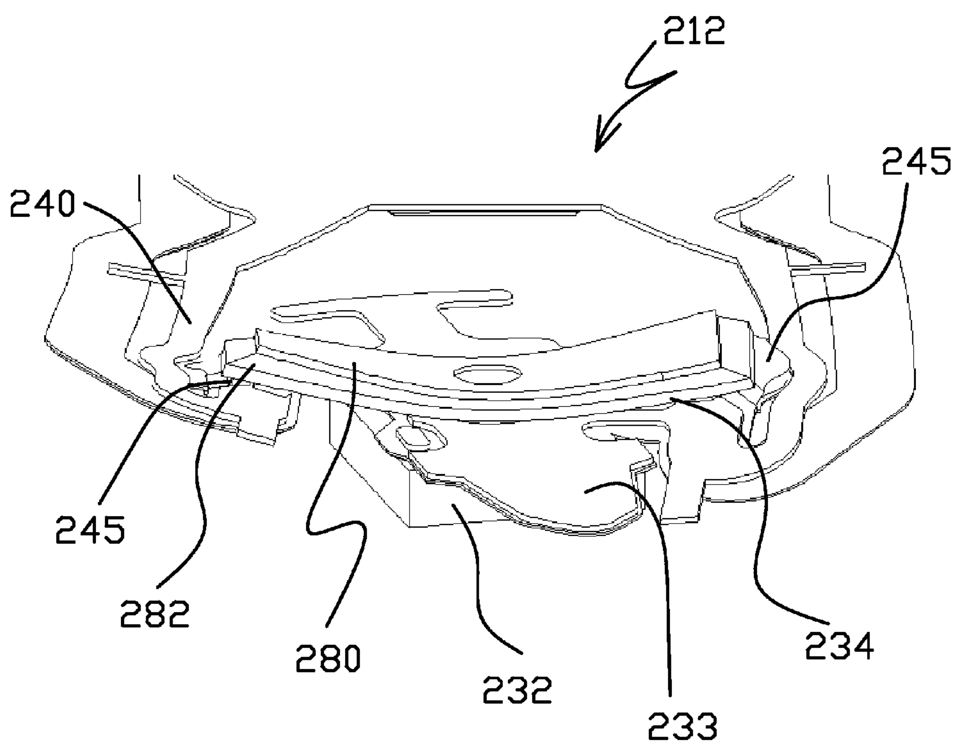

FIG 20

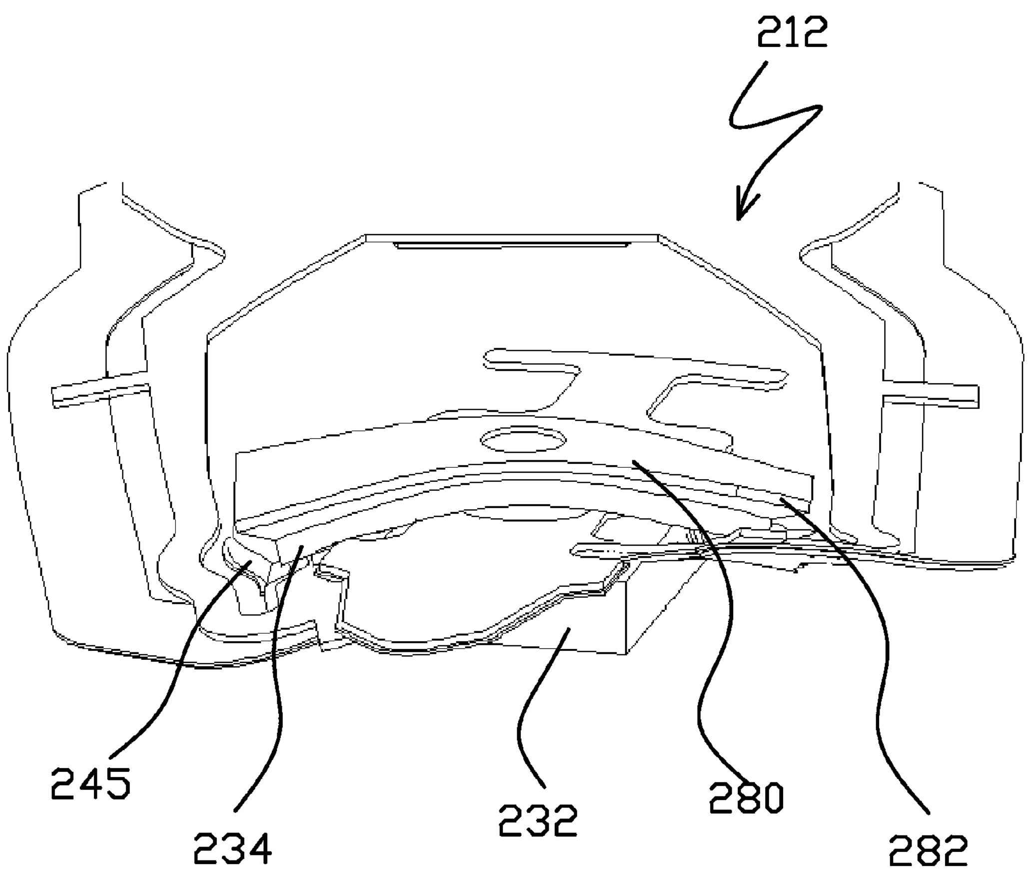

FIG 21

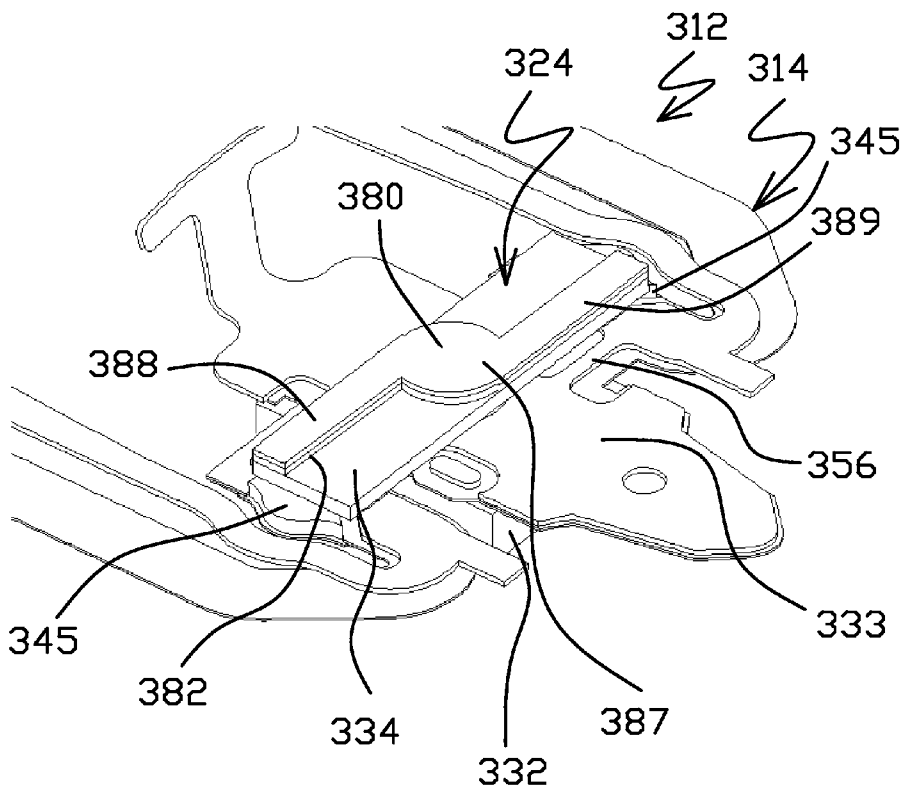

FIG 22

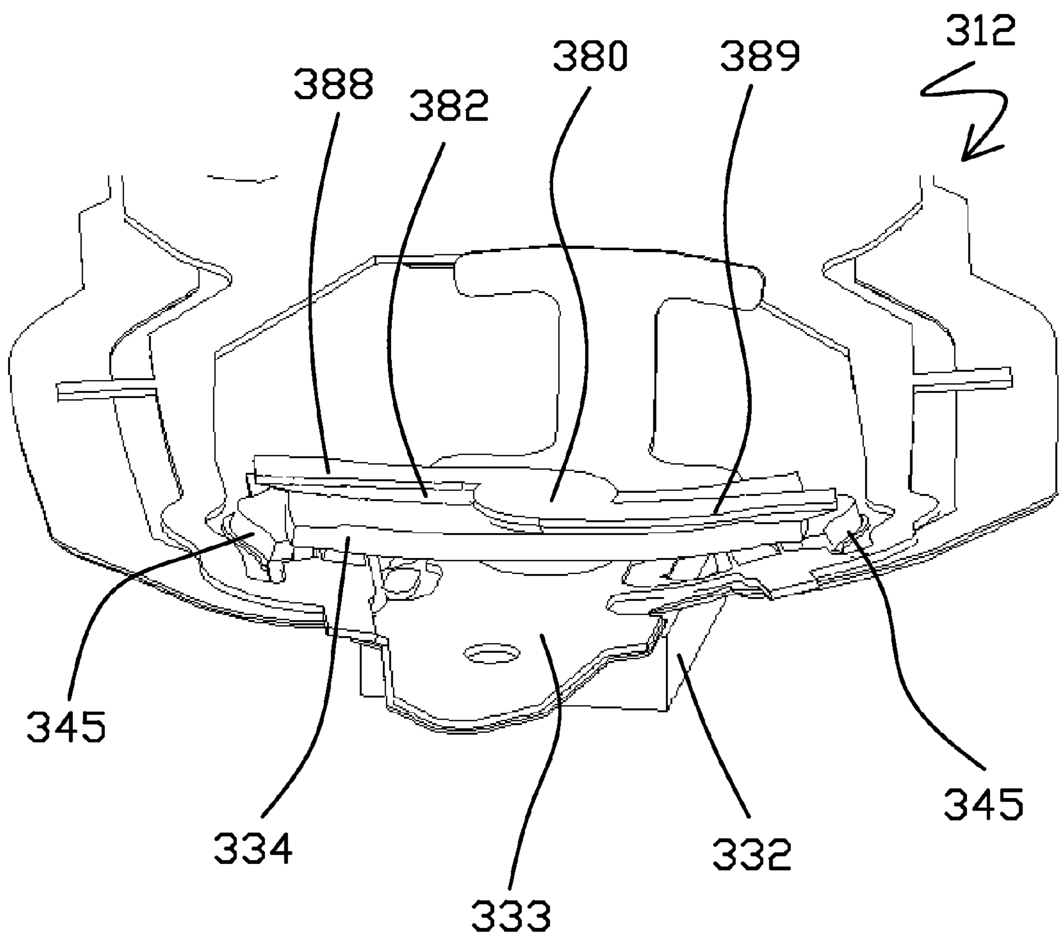

FIG 23

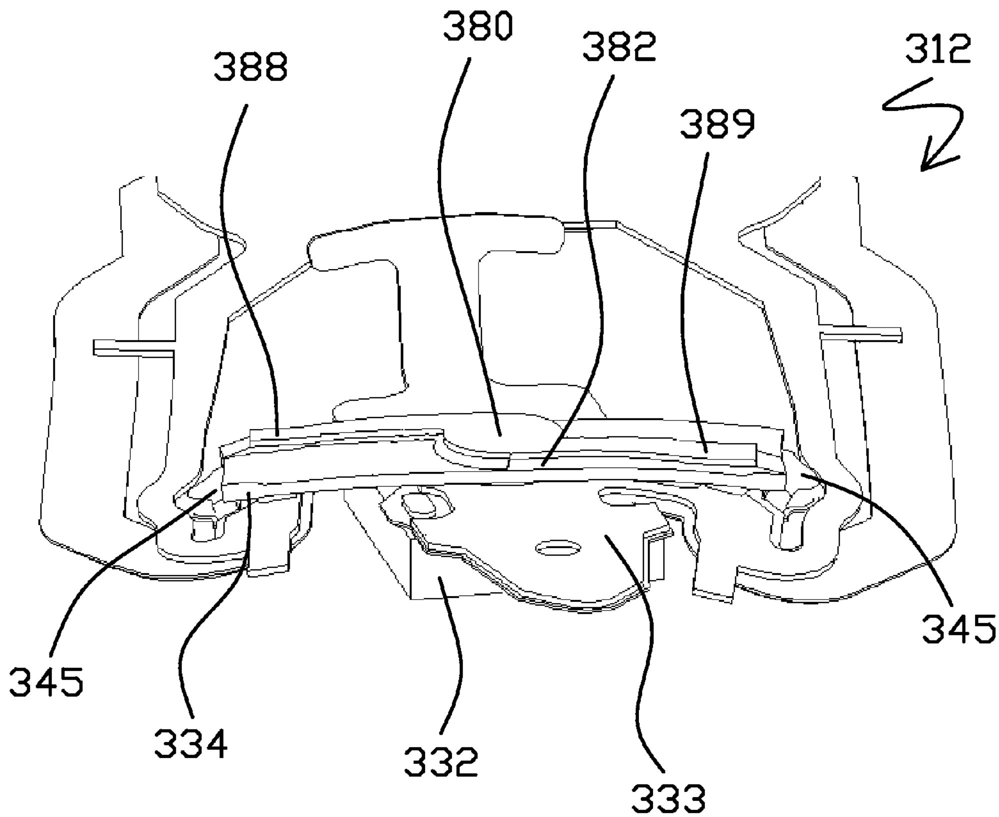

FIG 24

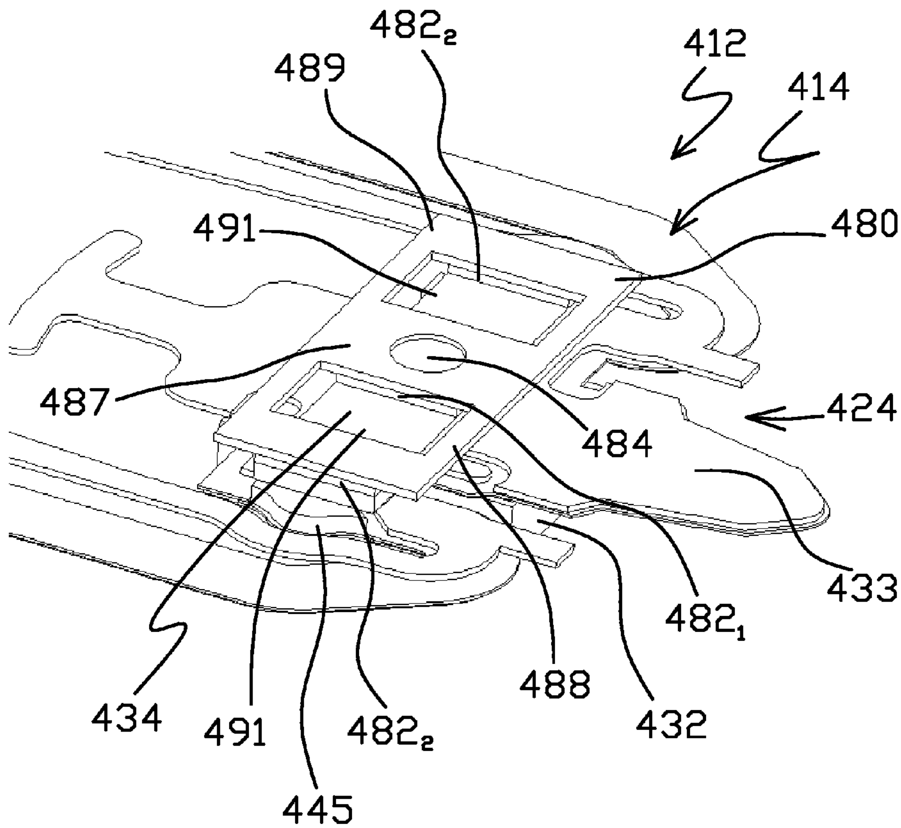
482$_2$
489
412
414
491
480
487
484
424
433
482$_1$
434
491
482$_2$
488
432
445

FIG 25

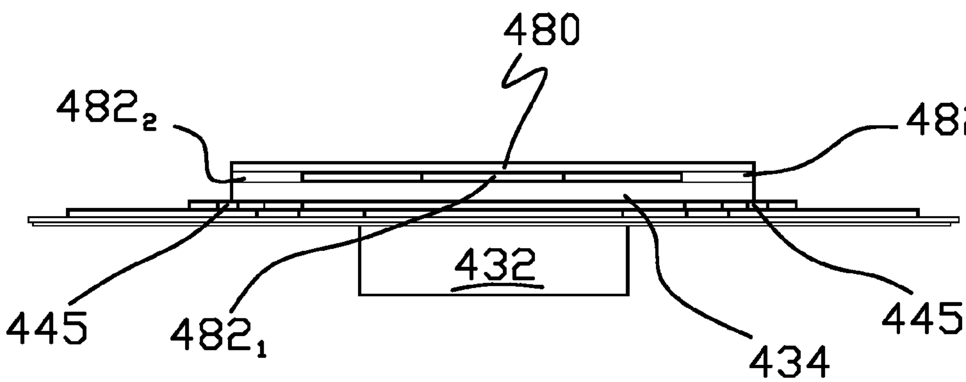

FIG 26

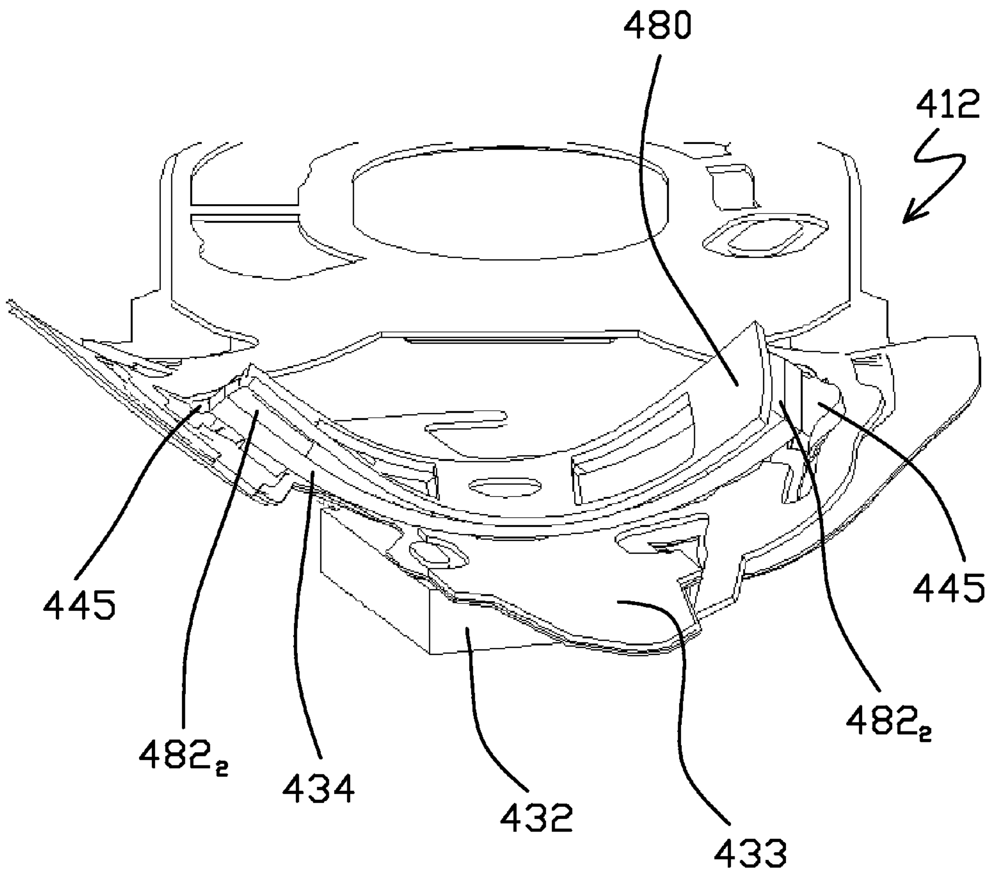

FIG 27

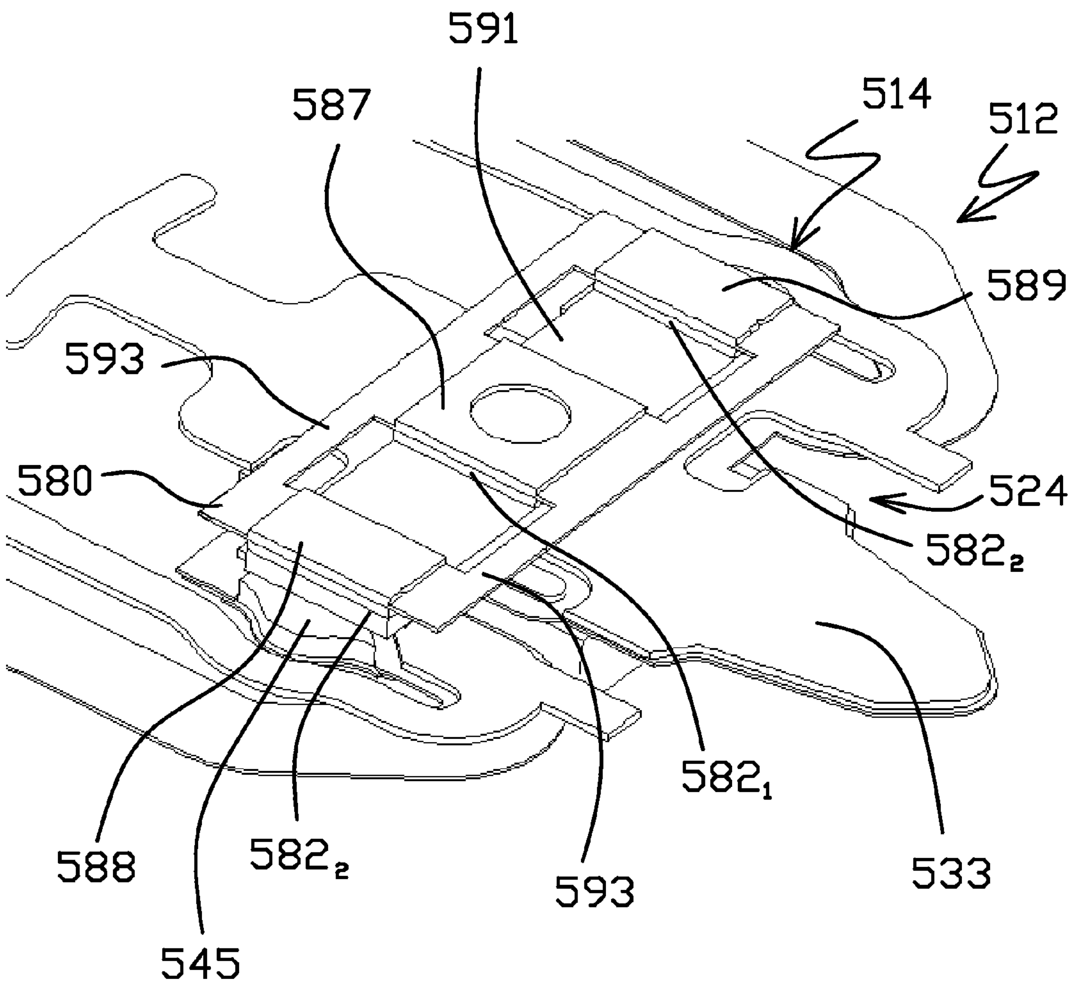

FIG 28

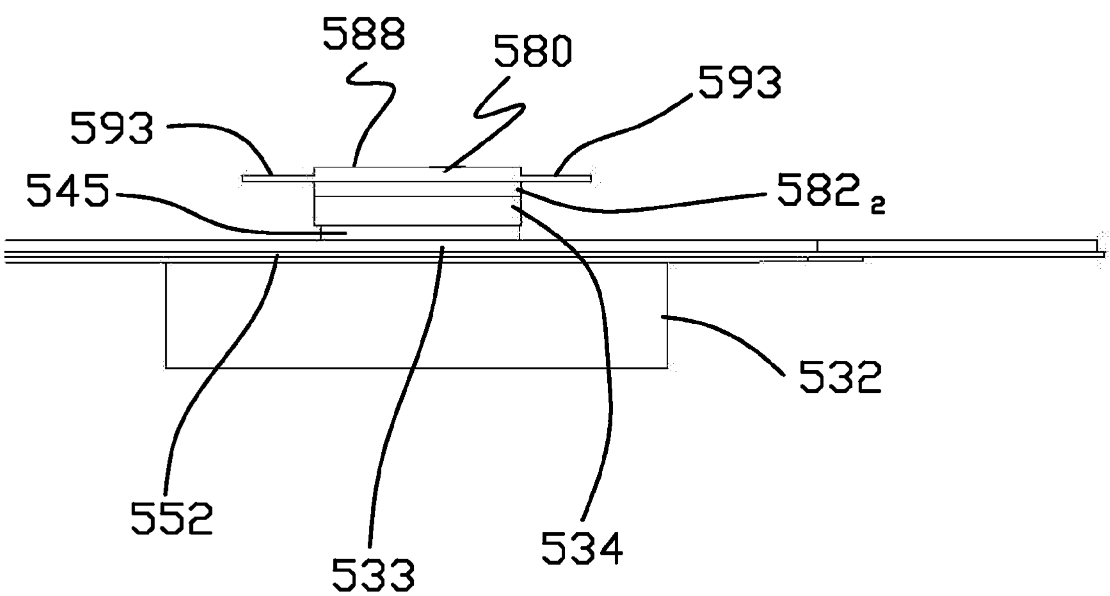

FIG 29

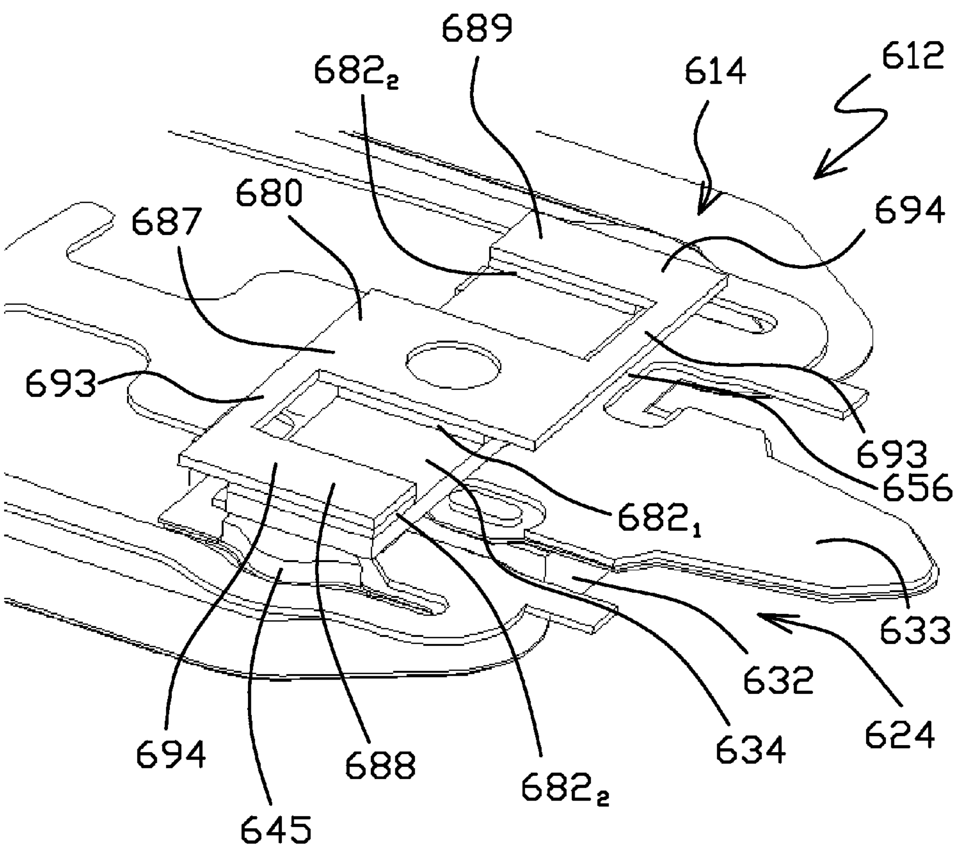
689
682_2
614
612
680
687
694
693
693
656
682_1
633
632
624
634
694
688
682_2
645

FIG 30

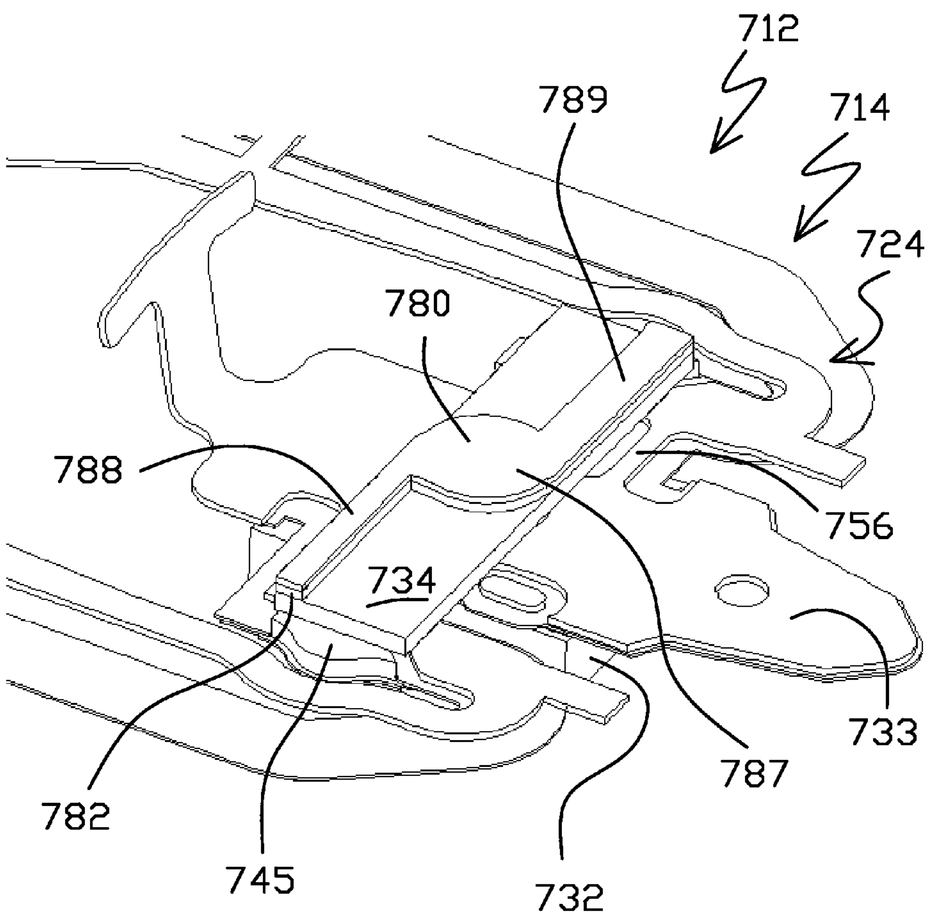

FIG 31

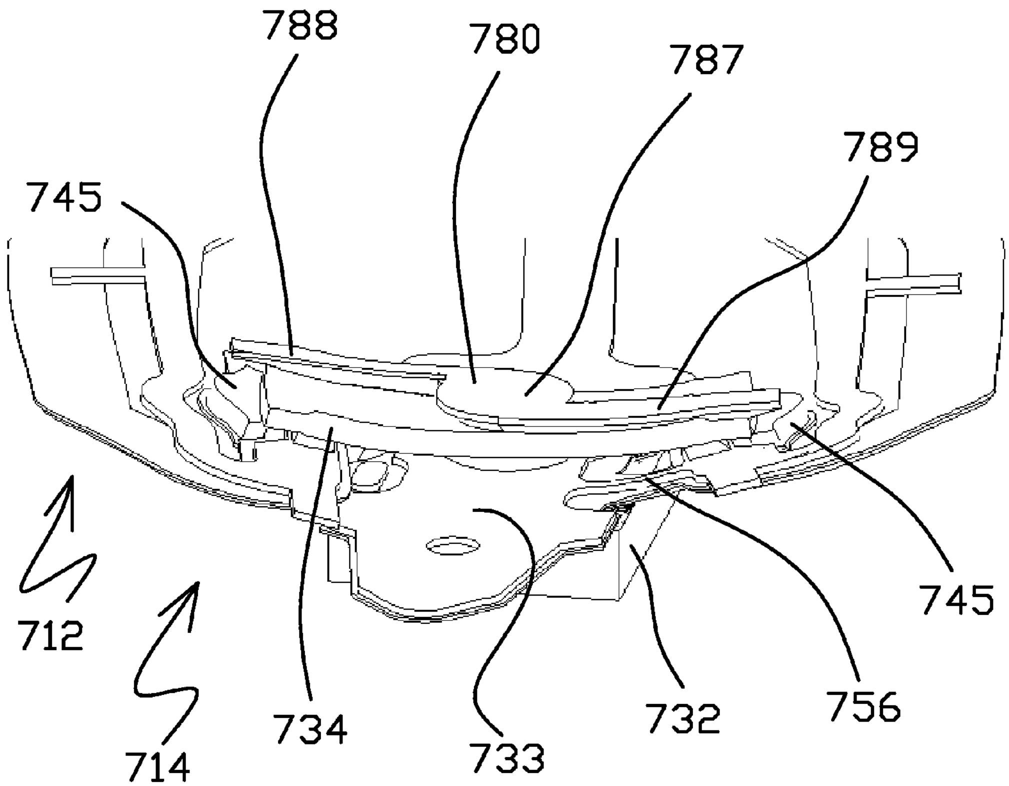

FIG 32A

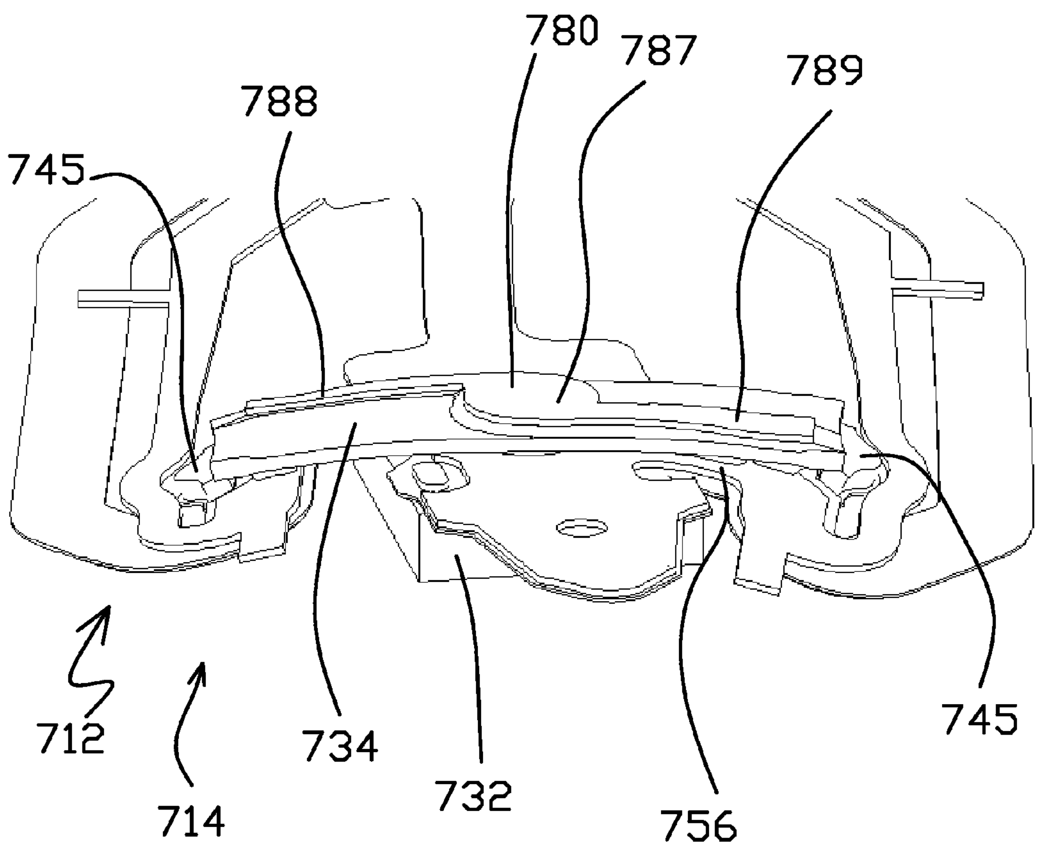

FIG 32B

CO-LOCATED GIMBAL-BASED DUAL STAGE ACTUATION DISK DRIVE SUSPENSIONS WITH MOTOR STIFFENERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 14/044,238, filed Oct. 2, 2013, now U.S. Pat. No. 8,891,206, issued Nov. 18, 2014, which claims the benefit of U.S. Provisional Application No. 61/738,167, filed Dec. 17, 2012, which is herein incorporated by reference in its entirety and for all purposes.

TECHNICAL FIELD

The present invention relates to disk drives and suspensions for disk drives. In particular, the invention is a dual stage actuation (DSA) suspension having a motor with a stiffener mounted thereon.

BACKGROUND

Dual stage actuation (DSA) disk drive head suspensions and disk drives incorporating DSA suspensions are generally known and commercially available. For example, DSA suspensions having an actuation structure on the baseplate or other mounting portion of the suspension, i.e., proximal to the spring or hinge region of the suspension, are described in the Okawara U.S. Patent Publication No. 2010/0067151, the Shum U.S. Patent Publication No. 2012/0002329, the Fuchino U.S. Patent Publication No. 2011/0242708 and the Imamura U.S. Pat. No. 5,764,444. DSA suspensions having actuation structures located on the loadbeam or gimbal portions of the suspension, i.e., distal to the spring or hinge region, are also known and disclosed, for example, in the Jurgenson U.S. Pat. No. 5,657,188, the Krinke U.S. Pat. No. 7,256,968 and the Yao U.S. Patent Publication No. 2008/0144225. Co-located gimbal-based DSA suspensions are disclosed in co-pending U.S. Provisional Application Nos. 61/700,972 and 61/711,988. All of the above-identified patents and patent applications are incorporated herein by reference in their entirety and for all purposes.

There remains a continuing need for improved DSA suspensions. DSA suspensions with enhanced performance capabilities are desired. The suspensions should be capable of being efficiently manufactured.

SUMMARY

Various embodiments concern a gimbaled flexure having a dual stage actuation structure comprising flexure. The gimbaled flexure comprises at least one spring arm and a tongue connected to the at least one spring arm. A motor is mounted on the gimbal. The motor comprises a top side and a bottom side opposite the top side. The bottom side of the motor faces the flexure. A stiffener is mounted on the top side of the motor. The stiffener can be stiffer than a portion of the gimbal on which the motor is mounted. The stiffener limits the degree of bending of the motor during activation of the motor. The stiffener can counteract the mechanical bending influence of the portion of the gimbal on which the motor is mounted. The stiffener can be asymmetric to balance and specifically configure bending characteristics.

Various embodiments concern a gimbaled flexure having a dual stage actuation structure. The flexure comprises a gimbal which includes a pair of spring arms, a pair of struts, and a tongue between the spring arms. A motor is mounted on the gimbal. The motor comprises a top side and a bottom side opposite the top side. The bottom side of the motor faces the flexure. A stiffener is mounted on the top side of the motor. At least one layer of adhesive is located between the stiffener and the motor and bonded to the stiffener and the motor. The gimbaled flexure includes a slider mounting for attaching a slider, such as to the tongue. The motor bends the struts to move the slider mounting about a tracking axis while the stiffener limits the degree of bending of the motor.

Further features and modifications of the various embodiments are further discussed herein and shown in the drawings. While multiple embodiments are disclosed, still other embodiments of the present disclosure will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of this disclosure. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an isometric view of the loadbeam side of a suspension having a flexure with a dual stage actuation (DSA) structure.

FIG. **2** is an isometric view of the loadbeam side of the distal end of the suspension shown in FIG. **1**.

FIG. **3** is an isometric view of the flexure side (i.e., the side opposite that shown in FIG. **2**) of the distal end of the suspension shown in FIG. **1**.

FIG. **4**A is an isometric view of the stainless steel side of the flexure shown in FIG. **1**.

FIG. **4**B is the view of FIG. **4**A but with the piezoelectric motor removed.

FIG. **5**A is an isometric view of the trace side (i.e., the side opposite that shown in FIG. **4**A) of the flexure shown in FIG. **1**.

FIG. **5**B is the view of FIG. **5**A but with the head slider removed.

FIG. **5**C is the view of FIG. **5**B but with the polyimide coverlay removed.

FIG. **5**D is the view of FIG. **5**C but with the conductive material layer removed.

FIG. **5**E is the view of FIG. **5**D but with the dielectric material layer removed.

FIG. **5**F is the view of FIG. **5**E but with the piezoelectric motor removed.

FIG. **6** is a side view of the distal end of the suspension shown in FIG. **1**.

FIG. **7** is a closer view of the portion of FIG. **6** showing the dimple, motor, and head slider.

FIGS. **8**A-**8**C are plan views of the stainless steel side of the flexure shown in FIG. **1**, illustrating the operation of the DSA structure.

FIG. **9** is an isometric view of the loadbeam side of a suspension having a flexure with a dual stage actuation (DSA) structure.

FIG. **10** is an isometric view of the loadbeam side of the distal end of the suspension shown in FIG. **9**.

FIG. **11** is an isometric view of the flexure side (i.e., the side opposite that shown in FIG. **10**) of the distal end of the suspension shown in FIG. **9**.

FIG. **12** is an isometric view of the stainless steel side of the flexure shown in FIG. **9**.

FIG. **13**A is an isometric view of the trace side (i.e., the side opposite that shown in FIG. **12**) of the flexure shown in FIG. **9**.

FIG. **13**B is the view of FIG. **13**A but with the head slider removed.

FIG. **13**C is the view of FIG. **13**B but with the motor removed.

FIG. **13**D is the view g of FIG. **13**C but with the coverlay removed.

FIG. **13**E is the view of FIG. **13**D but with the conductive material layer removed.

FIG. **13**F is the view of FIG. **13**E but with the dielectric material layer removed.

FIG. **14** is a side view of the distal end of the suspension shown in FIG. **9**.

FIG. **15** is a closer view of the portion of FIG. **14** showing the dimple, motor, and head slider.

FIGS. **16**A_1, **16**B_1, and **16**C_1 are plan views of the stainless steel side of the flexure shown in FIG. **9**.

FIGS. **16**A_2, **16**B_2, and **16**C_2 are plan views of the trace side of the flexure shown in FIGS. **16**A_1, **16**B_1, and **16**C_1, respectively.

FIG. **17** is an isometric view of a tri-stage actuated suspension.

FIG. **18** is an isometric view of the stainless steel side of the distal end of a flexure having a DSA structure with a stiffener.

FIG. **19** is a side view of the distal end of the flexure shown in FIG. **18**.

FIG. **20** is an illustration of the flexure shown in FIG. **18** when the motor is actuated into an expanded state.

FIG. **21** is an illustration of the flexure shown in FIG. **18** when the motor is actuated into a contracted state.

FIG. **22** is an isometric view of the stainless steel side of the distal end of a flexure having a DSA structure with an asymmetric stiffener.

FIG. **23** is an illustration of the flexure shown in FIG. **22** when the motor is actuated into a contracted state.

FIG. **24** is an illustration of the flexure shown in FIG. **22** when the motor is actuated into an expanded state.

FIG. **25** is an isometric view of the stainless steel side of the distal end of a flexure having a DSA structure with a stiffener and multiple adhesives.

FIG. **26** is a distal end view of the flexure shown in FIG. **25**.

FIG. **27** is an illustration of the flexure shown in FIG. **25** when the motor is actuated into an expanded state.

FIG. **28** is an isometric view of the stainless steel side of the distal end of a flexure having a DSA structure with a multiple thickness stiffener attached to the motor with multiple adhesives.

FIG. **29** is a detailed side view of the distal end of the flexure shown in FIG. **28**.

FIG. **30** is an isometric view of the stainless steel side of the distal end of a flexure having a DSA structure with an asymmetric stiffener attached to the motor with multiple adhesives.

FIG. **31** is an isometric view of the stainless steel side of the distal end of a flexure having a DSA structure with an asymmetric stiffener.

FIGS. **32**A and **32**B are illustrations of the flexure shown in FIG. **31** when the motor is actuated into contracted and expanded states, respectively.

DESCRIPTION OF THE INVENTION

FIG. **1** is an isometric view of the loadbeam side of a suspension **10** having a flexure **12** with a co-located or gimbal-based dual stage actuation (DSA) structure **14** in accordance with a first embodiment of this disclosure (i.e., a stainless steel side version). FIG. **2** is a detailed isometric view of the distal end of the suspension **10**. FIG. **3** is a detailed isometric view of the flexure side of the distal end of the suspension **10**, which shows the side opposite that shown in FIG. **2**. As shown in FIG. **1**, the suspension **10** includes a baseplate **16** as a proximal mounting structure. As further shown in FIG. **1**, the suspension **10** includes a loadbeam **18** having a rigid or beam region **20** coupled to the baseplate **16** along a spring or hinge region **22**. The loadbeam **18** can be formed from stainless steel.

Flexure **12** includes a gimbal **24** at the distal end of the flexure **12**. A DSA structure **14** is located on the gimbal **24**, adjacent the distal end of the loadbeam **18**. As best shown in FIG. **2**, the suspension **10** includes a gimbal limiter **26** comprising a tab **28** configured to engage a stop portion **30** of the loadbeam **18**. A head slider **32** is mounted to a slider mounting or tongue **33** of the gimbal **24**, on the side of the suspension **10** that is opposite the loadbeam **18**. DSA structure **14** includes a motor **34**, which is a PZT or other piezoelectric actuator in the illustrated embodiment, mounted to the gimbal **24** of the flexure **12** between the loadbeam **18** and the head slider **32**. As described in greater detail below, in response to electrical drive signals applied to the motor **34**, the motor drives portions of the gimbal **24**, including the tongue **33** and slider **32**, about a generally transverse tracking axis. Proximal and distal, as used herein, refers to the relative direction along the longitudinal axis of the suspension while lateral refers to the left and/or right directions orthogonal to the longitudinal axis of the suspension. For example, the baseplate **16** is proximal of the loadbeam **18** while opposite ends of the motor **34** extend laterally.

FIGS. **4**A and **4**B are isometric views of the stainless steel side of the flexure **12** and DSA structure **14** shown in FIG. **1**. The motor **34** is not shown in FIG. **4**B to show further details of the tongue **33**. FIGS. **5**A-**5**F are isometric views of the trace side (i.e., the side opposite that shown in FIGS. **4**A and **4**B) of the flexure **12** and DSA structure **14**. Specifically, FIGS. **5**A-**5**F show the various layers that comprise the flexure **12** and DSA structure **14**. FIG. **5**B is the drawing of FIG. **5**A but with the head slider **32** removed to further show details of the tongue **33**. FIG. **5**C is the drawing of FIG. **5**B but with a polyimide coverlay **46** removed to reveal a conductive material layer **44** including traces **60** and other structures formed in the conductive material layer that is otherwise underneath the polyimide coverlay **46**. FIG. **5**D is the drawing of FIG. **5**C but with the conductive material layer **44** removed to more fully reveal the dielectric layer **42** that is otherwise underneath the conductive material layer **44**. FIG. **5**E is the drawing of FIG. **5**D but with the dielectric layer **42** removed to show only the stainless steel layer **40** and the motor **34**. FIG. **5**F is the drawing of FIG. **5**E but with the motor **34** removed to illustrate only the stainless steel layer **40** of the flexure **12**. It will be understood that the stainless steel layer **40** could alternatively be formed from another metal or rigid material.

As shown in FIGS. **5**A-**5**F, the flexure **12** is formed from overlaying spring metal such as stainless steel layer **40**, polyimide or other dielectric layer **42**, copper or other conductive material layer **44** and polyimide coverlay **46**. The dielectric layer **42** generally electrically isolates structures formed in the conductive material layer **44** from adjacent portions of the stainless steel layer **40**. Coverlay **46** generally covers and protects the structures formed in the conductive material layer **44**. The gimbal **24** includes the spring arms **52** and the tongue **33**. The spring arms **52** extend from the base portion **50**. The mounting portion **54**, which is part of the tongue **33**, is supported between the spring arms **52** by a pair of struts **56** that extend from support regions **58** on the distal end portions of the spring arms **52**. In some embodiments, the pair of struts **56** is the only part of the stainless steel layer **40** that connects or otherwise supports the tongue **33** between the spring arms **52**.

Specifically, the struts **56** can be the only structural linkage between the spring arms **52** and the tongue **33**. Also, the struts **56**, in connecting with the tongue **33**, can be the only part of the stainless steel layer **40** that connects between the spring arms **52** distal of the base portion **50**. As shown, the struts **56** are offset from one another with respect to the longitudinal axis of the flexure **12** or otherwise configured so as to provide for rotational movement of the mounting portion **54** about the tracking axis with respect to the spring arms **52**. As best shown in FIG. **8**B (further discussed herein), one strut **56** of the pair of struts **56** is located proximally of the motor **34** while the other strut **56** of the pair of struts **56** is located distally of the motor **34** such that the motor **34** is between the pair of struts **56**. Each strut **56** has a longitudinal axis that extends generally perpendicular with respect to the longitudinal axis of the suspension **10**. The longitudinal axes of the struts **56** extend parallel but do not intersect or otherwise overlap with each other when the struts **56** are not stressed (e.g., not bent). As shown in FIG. **5**F, the struts **56** can each be the narrowest part of the stainless steel layer **40** in an X-Y plane (as viewed from the overhead perspective of FIG. **8**B) while the thickness of the stainless steel layer **40** can be consistent along the flexure **12**.

As perhaps best shown in FIGS. **4**A and **5**E, the opposite ends of the motor **34** are attached (e.g., by structural adhesive such as epoxy) to the support regions **58** of the spring arms **52**. In this way, the support regions **58** can serve as motor mounting pads. Portions of the dielectric layer **42** extend underneath the struts **56** in FIG. **4**B. As shown in FIG. **5**C, a plurality of traces **60** formed in the conductive material layer **44** extend between the base portion **50** and the tongue **33** over supporting portions **62** formed in the dielectric layer **42**. A number of the traces **60** terminate at locations on a distal region on the tongue **33** and are configured to be electrically attached to terminals of the read/write head (not shown) on the slider **32**. Other traces **60** terminate at a contact such as copper pad **64** on the tongue **33**, below the motor **34**. In the illustrated embodiment, the copper pad **64** is located generally centrally between the spring arms **52**. As perhaps best shown in FIG. **4**B, the dielectric layer **42** has an opening over the pad **64**. A structural and electrical connection, e.g., using conductive adhesive, is made between the copper pad **64** and an electrical terminal on the motor **34**. Another electrical connection to a terminal on the motor **34** (e.g., a ground terminal) is made through the dimple **36** (i.e., the dimple **36** is in electrical contact with the terminal on the motor **34**). In other embodiments, the electrical connections to the motor **34** can be made by other approaches and structures.

As shown in FIGS. **5**A and **5**B, the slider **32** sits on the coverlay **46** of the tongue **33**. Coverlay **46** provides protection for the traces **60**. As shown in FIGS. **5**A-**5**C, which show that the supporting portions **62** are offset with respect to the longitudinal direction of the flexure **12**, portions of the traces **60** on the opposite sides of the flexure **12** are offset from each other in a manner similar to that of the struts **56** (e.g., portions of the traces overlay the struts in the illustrated embodiment). Offset traces of this type can increase the stroke performance of the DSA structure **14**. Various other embodiments (not shown) do not have offset traces. It is noted that, in some embodiments, the supporting portions **62** may provide negligible mechanical support to the tongue **33** relative to the struts **56**.

FIGS. **6** and **7** are side views of the suspension **10**, illustrating the gimbal **24** and DSA structure **14**. As shown, the dimple **36**, which is a structure formed in the stainless steel material that forms the loadbeam **18**, and which extends from the loadbeam **18**, engages the motor **34** and functions as a load point by urging the portion of the gimbal **24** to which the motor **34** is connected out of plane with respect to the base portion **50** of the flexure **12**. A bend or transition in the flexure **12** can occur at any desired location along the spring arms **52** due to the urging of the gimbal **24** by the dimple **36**. The dimple **36** can also provide an electrical contact to a terminal (not visible) on the portion of the motor **34** engaged by the dimple. For example, if the stainless steel loadbeam **18** is electrically grounded or otherwise part of an electrical circuit, the dimple **36** can provide an electrical ground potential or electrical connection to the terminal on the motor **34**. Various other embodiments (not shown) include other dimple structures such as plated structures that provide these functions. The dimple **36** can be plated with conductive material such as gold to enhance the electrical connection to the terminal of the motor **34** which can also be plated with conductive material such as gold. Still other embodiments (not shown) use structures other than the dimple **36** to provide a grounding or other electrical connection to the motor **34**. In one such embodiment, for example, there is another copper pad on the end of one of the support regions **58**, and an electrical connection (e.g., a ground connection) can be made by a structure such as conductive adhesive between a terminal on the motor **34** and the conductive material pad on the support region of the flexure **12**. In some embodiments, the motor **34** is structurally attached to the tongue **33** at a location between the opposite lateral end portions of the tongue **33**. In such embodiments, the motor **34** is attached to the tongue **33** of the gimbal **24** in addition to the motor **34** being attached to the support regions **58** of the spring arms **52**.

The operation of DSA structure **14** can be described with reference to FIGS. **8**A-**8**C that are plan views of the stainless steel side of the gimbal **24** of the flexure **12**. As shown in FIG. **8**B, the DSA structure **14** and tongue **33** are in a neutral, undriven state with the tongue **33** generally centrally located between the spring arms **52** when no tracking drive signal is applied to the motor **34**. As shown in FIG. **8**A, when a first potential (e.g., positive) tracking drive signal is applied to the motor **34**, the shape of the motor changes and its length generally expands. This change in shape increases the distance between the support regions **58** as shown in FIG. **8**A, which in connection with the mechanical action of the linking struts **56**, causes the tongue **33** to move or rotate in a first direction with respect to the spring arms **52** about the tracking axis. As shown, the lengthening of the motor **34** stretches the gimbal **24** laterally and causes the struts **56** to bend (e.g., bow inward). Because of the offset arrangement of the struts **56**, the struts **56** bend such that the tongue **33** rotates in the first direction.

As shown in FIG. **8**C, when a second potential (e.g., negative) tracking drive signal is applied to the motor **34**, the shape of the motor changes and its length generally contracts. This change in shape decreases the distance between the support regions **58** as shown in FIG. **8**C, which in connection with the mechanical action of the linking struts **56**, causes the tongue **33** to move or rotate in a second direction with respect to the spring arms **52** about the tracking axis. The second direction is opposite the first direction. As shown, the shortening of the motor **34** compresses the gimbal **24** laterally and causes the struts **56** to bend (e.g., bow outward). Because of the offset arrangement of the struts **56**, the struts **56** bend such that the tongue **33** rotates in the second direction. Some, although relatively little, out-of-plane motion of other portions of the gimbal **24** is produced during the tracking action of DSA structure **14** as described above. With this embodiment of this disclosure, slider mounting on the tongue **33** generally rotates with respect to the spring arms **52** as the spring arms **52** stay stationary or experience little movement.

FIG. **9** is an isometric view of the loadbeam-side of a suspension **110** having a flexure **112** with a co-located or gimbal-based dual stage actuation (DSA) structure **114** in accordance with a second embodiment of this disclosure (i.e., a trace side version). The components of the suspension **110** can be configured similarly to the previously discussed suspension **10** unless otherwise described or illustrated. FIG. **10** is an isometric view of the distal end of the suspension **110**. FIG. **11** is an isometric view of the flexure-side of the distal end of the suspension **110**, showing the side opposite that shown in FIG. **10**. As shown in FIG. **10**, the suspension **110** includes a baseplate **116** as a proximal mounting structure. As further shown in FIG. **11**, the suspension **110** includes a loadbeam **118** having a rigid or beam region **20** coupled to the baseplate **116** along a spring or hinge region **122**. The loadbeam **18** can be formed from stainless steel. Flexure **112** includes a gimbal **124** at its distal end. A DSA structure **114** is located on the gimbal **124**, adjacent the distal end of the loadbeam **118**. The illustrated embodiment of the suspension **110** also includes a gimbal limiter **126** comprising a tab **128** configured to engage a stop portion **130** of the loadbeam **118**. The DSA structure **114** includes a motor **134**, which is a PZT actuator in the illustrated embodiment, mounted to a motor mounting region of the tongue **133**, on the side of the flexure **112** opposite the loadbeam **118**. A head slider **132** is mounted to the side of the motor **134** opposite the flexure **112**. As described in greater detail below, in response to electrical drive signals applied to the motor **134**, the motor drives portions of the gimbal **124**, including portions of the tongue **133**, motor **134** and slider **132**, about a generally transverse tracking axis.

FIG. **12** is a detailed isometric view of the stainless steel-side of the flexure **112** and DSA structure **14** shown in FIG. **9**. FIGS. **13**A-**13**F are isometric views of the flexure **112** and DSA structure **114** showing the side opposite that shown in FIG. **12**. Specifically, FIGS. **13**A-**13**F show the various layers that comprise the flexure **112** and DSA structure **114**. FIG. **13**B is the drawing of FIG. **13**A but with the head slider **132** removed to further show details of the motor **134** on the tongue **133**. FIG. **13**C is the drawing of FIG. **13**B but with the motor **134** removed to reveal details of the tongue **133**. FIG. **13**D is the drawing of FIG. **13**C but with the coverlay **146** removed to reveal a conductive material layer **144** including traces **160** and other structures formed in the conductive material layer **144**. FIG. **13**E is the drawing of FIG. **13**D but with the conductive material layer **144** removed to further reveal the dielectric layer **142**. FIG. **13**F is the drawing of FIG. **13**E but with the dielectric layer **142** removed to show only the stainless steel layer **140** of the flexure **112**. It will be understood that the stainless steel layer **140** could alternatively be formed from another metal or rigid material. As shown, the flexure **112** is formed from overlaying spring metal such as stainless steel layer **140**, polyimide or other dielectric layer **142**, copper or other conductive material layer **144**, and coverlay **146**. The dielectric layer **142** generally electrically isolates structures formed in the conductive material layer **144** from adjacent portions of the stainless steel layer **140**. Coverlay **146** generally covers and protects the structures formed in the conductive material layer **144**.

The gimbal **124** includes spring arms **152** and the tongue **133**. The base portion **150**, the spring arms **152**, and the center region **154** are each formed from the stainless steel layer **140**. The spring arms **152** extend from the base portion **150**. The center region **154**, which is a center part of the tongue **133**, is connected to the distal ends of the spring arms **152** and is supported between the spring arms **152**. Also formed in the stainless steel layer **140** is a pair of struts **153**. Each of the struts **153** extends from one of the opposite lateral sides of the center region **154** and has a motor mounting flag or pad **155** on its outer end. As shown, the struts **153** are offset from one another with respect to the longitudinal axis of the flexure **112** or otherwise configured so as to provide for rotational movement of the motor **134** and the head slider **132** mounted thereto about the tracking axis with respect to the center region **154**. Each strut **153** comprises a longitudinal axis that extends generally perpendicular with respect to the longitudinal axis of the suspension **110**. The longitudinal axes of the struts **153** extend parallel but do not intersect or otherwise overlap with each other when the struts **153** are not stressed (e.g., not bent). The struts **153** can be the only structural linkage between the center region **154** and the pads **155** (e.g., the only part of the stainless steel layer **140** connecting the center region **154** with the pads **155** is the struts **153**, a single strut **153** for each pad **155**). As shown in FIG. **13**F, the struts **153** can each be the narrowest part of the stainless steel layer **140** in an X-Y plane (as viewed from the overhead perspective of FIG. **16**B_1) while the thickness of the stainless steel layer **140** can be consistent along the flexure **112**.

As shown in FIG. **13**D, a plurality of traces **160** are formed in the conductive material layer **144** and extend between the base portion **150** and tongue **133** along paths generally laterally outside the spring arms **152** and over supporting portions **162** formed in the dielectric layer **142**. A number of the traces **160** terminate at locations adjacent the distal region of the tongue **133** and are configured to be electrically attached to read/write head terminals (not shown) on the slider **132**. A pair of power traces **161** for powering the motor **134** are also formed in the conductive material layer **144**, and extend between the base portion **150** and a proximal portion of the tongue **133** along paths generally inside the spring arms **152** and over supporting portions **163** formed in the dielectric layer **142**. The motor power traces **161** terminate at a first motor terminal pad **167** on one of the motor mounting pads **155**. A second motor terminal pad **169** is formed in the conductive material layer **144** on the other motor mounting pad **155**, and is coupled by a trace **171** to a conductive via **173** that is shown on the tongue **133** at a location between the motor mounting pads **155**. As best viewed in FIG. **13**D, via **173** extends through an opening **175** in the dielectric layer **142** (shown in FIG. **13**E) to electrically contact the stainless steel layer **140** of the flexure **112**. The motor terminal pad **169** can be electrically connected to a ground potential at the stainless steel layer **140** by the trace **171** and the via **173**. As shown in FIG. **12**, structures such as tabs **157** in the stainless steel layer **140** are formed out of the plane of the stainless steel layer and engage the distal portion of the trace supporting portions **162** to push the terminal ends of the traces **161** down so the terminals on the slider **132** can be correctly electrically attached (e.g., by solder bonds) to the traces while accommodating the thickness of the motor **134**. FIG. **13**E also illustrates other holes in the dielectric layer that can be used in connection with conductive vias to electrically connect (e.g., ground) traces and other structures in the conductive material layer **144** to the stainless steel layer **140**. In other embodiments, other approaches and structures can be used to couple the tracking drive signals to the terminals on the motor **134**.

The electrical terminals on the motor **134** may be on the same side (e.g., top or bottom) but opposite longitudinal ends of the motor **134**. As shown in FIGS. **13**B and **13**C, the motor **134** can be attached to the gimbal **124** by bonding the electrical terminals of the motor **134** to the motor terminal pads **167** and **169** using conductive adhesive. By this approach, the motor **134** is both structurally and electrically connected to the gimbal **124**. As shown in FIG. **13**C, the motor terminal pads **167** and **169** are exposed through openings in the coverlay **146** to provide access for the conductive adhesive.

FIGS. **14** and **15** are side views of the suspension **110**, illustrating the gimbal **124** and DSA structure **114**. As shown, the dimple **136**, which is a structure formed in the stainless steel of the loadbeam **118** and which projects from the loadbeam **118**, engages the center region **154** of stainless steel layer **140** on the side of the tongue **133** opposite the motor **134**. Dimple **136** functions as a load point by urging the portion of the gimbal **124** to which the motor **134** is connected out of plane with respect to the base portion **150** of the flexure **112**. In the illustrated embodiment, the motor **134** is located between the tongue **133** and the head slider **132** (e.g., the motor **134** is sandwiched in a vertical axis). As shown in FIGS. **14** and **15**, the slider **132** is structurally supported by the motor **134** such that the only structural linkage between the flexure **112** and the slider **132** runs through or otherwise includes the motor **134**. The manner by which the stainless steel tabs **157** locate the portion of dielectric layer **142** with the terminal ends of the traces **160** at the correct z-height and adjacent to the portion of the head slider **132** that includes the read/write head terminals is shown in FIG. **15**.

The operation of DSA structure **114** can be described with reference to FIGS. **16**A_1, **16**A_2, **16**B_1, **16**B_2, **16**C_1 and **16**C_2 that are plan views of the gimbal **124** of the flexure **112**. FIGS. **16**A_1, **16**B_1 and **16**C_1 illustrate the stainless steel side of the flexure **112**, and FIGS. **16**A_2, **16**B_2 and **16**C_2 illustrate the trace side of the flexure **112**, with the motor **134** and head slider **132** shown. As shown in FIGS. **16**B_1 and **16**B_2, the DSA structure **114** and tongue **133**, as well as the motor **134** on the linkage formed by the motor mounting pads **155** and struts **153**, are in a neutral, undriven state with the head slider positioned generally parallel to the longitudinal axis of the flexure **112** when no tracking drive signal is applied to the motor **134**. The struts **153** are not bent or otherwise stressed in this state. As shown in FIGS. **16**A_1 and **16**A_2, when a first potential (e.g., positive) tracking drive signal is applied to the motor **134**, the shape of the motor changes and its length generally expands. This change in shape increases the distance between the motor mounting pads **155**, which in connection with the mechanical action of the linking struts **153**, causes the motor **134**, and therefore the head slider **132** mounted thereto, to move or rotate in a first direction with respect to the longitudinal axis of the flexure **112** about the tracking axis. As shown, the lengthening of the motor **134** stretches the struts **153** laterally and causes the struts **153** to bend (e.g., bow inward). Because of the offset arrangement of the struts **153**, the struts **153** bend such that the motor **134** and the head slider **132** rotate in the first direction.

As shown in FIGS. **16**C_1 and **16**C_2, when a second potential (e.g., negative) tracking drive signal is applied to the motor **134**, the shape of the motor changes and its length generally contracts. This change in shape decreases the distance between the motor mounting pads **155**, which in connection with the mechanical action of the linkage including struts **153**, causes the motor **134**, and therefore the head slider **132** mounted thereto, to move or rotate in a second direction with respect to the longitudinal axis of the flexure **112** about the tracking axis. The second direction is opposite the first direction. As shown, the shortening of the motor **134** compresses the struts **153** laterally and causes the struts **153** to bend (e.g., bow outward). Because of the offset arrangement of the struts **153**, the struts **153** bend such that the motor **134** and the head slider **132** rotate in the second direction.

Some, although relatively little, out-of-plane motion of other portions of the gimbal **124** may be produced during the tracking action of DSA structure **114**. The linkage provided by the struts **153** accommodates the motion of the motor **134** so the remaining portions of the tongue **133** remain generally aligned with respect to the longitudinal axis of the flexure **112** during this tracking action. For example, the motor **134** and slider **132** rotate, but the center region **154** (or more broadly the tongue **133**) does not rotate or rotates only an insignificant or trivial amount.

FIG. **17** is an illustration of a suspension **210** in accordance with another embodiment of this disclosure. As shown, the suspension **210** includes a co-located or gimbal-based DSA structure **214** and a loadbeam or baseplate-type DSA structure **290**. In this way, the suspension **210** is a tri-stage actuated suspension. In one embodiment, the DSA structure **214** is substantially the same as the DSA structure **114** described above (e.g., is configured with any aspect described or shown in connection with FIGS. **9**-**16**C_2) except as otherwise specified or shown. In another embodiment, the DSA structure **214** is substantially the same as the DSA structure **14** described above (e.g., is configured with any aspect described or shown in connection with FIGS. **1**-**8**C) except as otherwise specified or shown. Other embodiments of suspension **210** include other gimbal-based DSA structures. The DSA structure **290** can be any known or conventional DSA structure such as any of those described above in the background section.

Bowing, twisting, and/or asymmetric bending can be present in various suspensions such as those described above. For example, returning the suspension of FIGS. **1**-**8**C, when the motor **34** on the suspension **10** is actuated to expand, the motor **34** can vertically deflect by bowing such that the lateral ends of the motor **34** move toward the slider **32** and the stainless steel layer **40** of the gimbal **24** relative to the middle of the motor **34**. In other words, upon expansion, the lateral ends of the motor **34** bend downward and/or the middle of the motor **34** bends upwards. The deflection of the motor **34** in this manner can be due to the resistance provided by the gimbal **24**. For example, the gimbal **24**, being on one side of the motor **34** while the other side of the motor **34** is unrestrained, resists the expansion of the motor **34** and therefore causes the motor **34**, along with the attached gimbal **24**, to vertically deflect. Conversely, when the motor **34** is electrically activated with the opposite polarity to contract, the motor **34** can deflect by bowing in the opposite direction such that the lateral ends of the motor **34** move away the slider **32** and the stainless steel layer **40** of the gimbal **24** relative to the middle of the motor **34** which moves toward the slider **32** and the stainless steel layer **40**. In other words, upon expansion, the lateral ends of the motor **34** bend upward and/or the middle of the motor **34** bends downwards. The deflection of the motor **34** in this manner can likewise be due to the resistance provided by the gimbal **24** on one side of the motor **34**. The vertical direction of this bending can reduce stroke efficiency of the motor **34**. For example, the motor **34** cannot fully extend or contract along its longitudinal axis when also bending in a vertical direction, and as such some stroking range is lost. Furthermore, the motor **34** can twist about its longitudinal axis (typically transversely oriented on the gimbal **24**) during expansion and contraction. This twist can be due to asymmetric bending stiffness of the offset gimbal struts **56**. Asymmetric bending and twisting can also lead to increased gimbal modes (natural frequencies) causing resonance performance issues. Reduced resonance performance can lead to lower servo bandwidth in the disk drives into which the suspensions are incorporated. This, in turn, can increase the distance that the individual tracks are spaced from each other on the disks, and thereby reduce the overall amount of data that can be packed onto the disk surface.

Various embodiments of this disclosure include a stiffener component that is bonded or otherwise attached to a side (e.g., a top or free side) of a motor. Such a stiffener can limit the bending of the motor and/or gimbal during motor activation. FIGS. **18-32**B show various embodiments of suspensions having a stiffener mounted on a motor to address the issues discussed above.

FIG. **18** is an isometric view of the stainless steel side of a flexure **212**. FIG. **19** is a side view of the flexure **212**. The flexure **212** is part of a DSA structure **214** that can be similar to that of the DSA structure **14** described above or other DSA structure referenced herein except where noted. Features of flexure **212** that are the same or similar to those of flexure **12** are indicated by similar reference numbers. A stiffener **280** is mounted on the motor **234**. The stiffener **280** is attached to the motor **234** by adhesive **282** disposed between the stiffener **280** and the motor **234**. Specifically, the adhesive **282** can be a layer of adhesive that is bonded to a bottom side of the stiffener **280** and a top side of the motor **234**. In the embodiment shown in FIG. **18**, the stiffener **280** is located over the entire top or free surface of the motor **234** (i.e., the surface of the motor **234** that is opposite the bottom side of the motor **234** that faces the tongue **233**). As shown, the four edges (lateral sides, front, and back) of the stiffener **280** are aligned with the four edges (lateral sides, front, and back) of the motor **234**.

The stiffener **280** will generally have sufficient stiffness to at least partially offset the stiffness of the portion of gimbal **224** that is resisting motion of the motor **234** and causing the stroke-reducing bending. In some embodiments, the stiffener **280** is made from metal such as stainless steel, aluminum, nickel, titanium or other structural metal. In various other embodiments, the stiffener **280** is formed from a polymer material. A polymer stiffener may have increased thickness (as compared to a metal stiffener) to provide the desired bending stiffness. The stiffener **280** can, for example, be etched, cut or otherwise formed from sheet or film stock. In some embodiments, the stiffener **280** can be about 10-25 μm in thickness. The stiffener can be thicker or thinner in other embodiments.

The embodiment of FIG. **18** further includes a reduced thickness region **284** at the center of the stiffener **280**. In this or in other ways, a stiffener can have a first thickness along a first portion of the stiffener and a second thickness along a second portion of the stiffener, the second thickness less than the first thickness. The reduced thickness region **284** can be a surface of the stiffener **280** that is positioned and configured to make contact with a load point dimple of the loadbeam (not shown). Reducing the thickness of the stiffener **280** at the dimple contact location can allow the dimple to extend into the cavity created by the reduced thickness region **284**, which reduces the overall height of the suspension **210** because the loadbeam can be closer to the flexure **212**. Various other embodiments do not include the partial thickness region **284**. Other configurations for a reduced thickness region are further discussed herein.

Adhesive **282** forms a relatively thin material layer between the motor **234** and stiffener **280** (e.g., about 2-25 μm in some embodiments). In some embodiments, the adhesive **282** has a relatively low elastic modulus to enhance the operation of the DSA structure **214**. Low elastic modulus adhesives **282** can provide reduced resistance of the stiffener **280** on expansion and contraction of the motor **234**, while still enhancing the bending stiffness of the DSA structure **214**. Embodiments of flexure **212** with adhesive **282** having an elastic modulus of about 100 MPa have demonstrated enhanced performance. Other embodiments can have adhesive **282** with a different elastic modulus.

The motor **234** is mounted on the flexure **212** by being connected to a pair of connectors **245**. The connectors **245** can connect with respective anode and cathode terminals of the motor **234**. The connectors **245** can further connect with respective traces running along the flexure **212** to electrically activate the motor **234**. The connectors **245** can comprise solder, conductive epoxy (e.g., silver filled), or other material for forming an electrode connection. The connectors **245** can structurally attach the motor **234** to the flexure **212**. Specifically, the pair of connectors **245** can connect the lateral ends of the motor **234** to the pair of spring arms **252**, respectively. The slider **232** is mounted to a slider mounting of the tongue **233**. The slider mounting is a surface of the tongue **233** to which the slider **232** can be attached, such as with an adhesive such as epoxy. Rotation of the tongue **333** by actuation of the motor **234** rotates the slider mounting, and thereby the slider **332**, about a tracking axis.

FIG. **20** is an isometric view of the flexure **212** and shows an example of a state of the flexure **212** when the motor **234** is electrically activated to expand to an expanded state. As shown, the motor **234** bends toward the stiffener **280** (i.e., in the direction opposite of the bending in embodiments of the same flexure **212** when the motor **234** expands without the stiffener **280**) such that the lateral ends of the motor **234** move away from the slider **232** and the stainless steel layer **240** relative to the middle of the motor **234** which moves toward the slider **232** and the stainless steel layer **240**. In other words, upon expansion while restrained by the stiffener **280**, the lateral ends of the motor **234** bend upward while the middle of the motor **234** bends downwards, which is the opposite bending profile had the stiffener **280** not been attached to the motor **235**. Conversely, FIG. **21** is the same isometric view of the flexure **212** as FIG. **20** when the motor **234** is electrically activated to contract. As shown, the motor **234** bends away the stiffener **280** (i.e., in the direction opposite of the bending in embodiments of the same flexure **212** when the motor **234** contacts without the stiffener **280**) such that the lateral ends of the motor **234** move toward the slider **232** and the stainless steel layer **240** relative to the middle of the motor **234** which moves away the slider **232** and the stainless steel layer **240**. In other words, upon contraction while restrained by the stiffener **280**, the lateral ends of the motor **234** bend downward while the middle of the motor **234** bends upwards, which is the opposite bending profile had the stiffener **280** not been attached to the motor **235**. However, it is noted that not all embodiments are so limited and that the stiffener **280** can change the bending profile of the flexure **212** in additional or alternative ways.

It is noted that the presence of the stiffener **280** on the motor **234** can change the amount of deflection of the motor **234** when contracted. This bending action is produced because the overall stiffness of the stiffener **280** and motor **234** is stronger than the stiffness of the associated portion of the flexure **212** (e.g., the stainless steel layer **240** specifically) on the other side of the motor **234** with respect to the stiffener **280**. In this way, the stiffener **280** can balance or counteract the stiffness of the flexure **212** about the motor **234** to control or limit vertical deflection. Limiting the vertical deflection increases the stroke because the motor **234** is allowed to more fully expand or contract along an axis that pushes or pulls the areas at which the motor **234** is attached to the flexure **212** to move the tongue **233** and the slider **232**. Increasing the stroke of the motor **234** increases the rotational stroke of the DSA structure **214**. In some embodiments, the stiffener **280** can increase the stroke by over 70% (e.g., over embodiments of a similar flexure without the stiffener **280**). As such, the presence and configuration (e.g., shape, elastic modulus) of the stiffener **280** can be balanced with the mechanics of the flexure **212** to minimize bending of the motor **234** and flexure **212**, maximize longitudinal stroke of the motor **234**, and/or reverse the bending profile of the motor **234**.

As shown in FIGS. **20** and **21**, the low modulus adhesive **282** deforms in shear during this actuation of the motor **234**. While the profile of the stiffener **280** is matched to the profile of the motor **234** when the motor **234** is not activated, as shown in FIG. **18**, the motor **234** extends beyond the lateral ends of the stiffener **280** in the embodiment of FIG. **20** as the motor **234** expands such that the respective profiles of the stiffener **280** and the motor **234** no longer match. In FIG. **20**, the adhesive **282** is shown stretching between the relatively larger profile of the motor **234** and the relatively smaller profile of the stiffener **280**. In FIG. **21**, the adhesive **282** is shown stretching between the relatively smaller profile of the motor **234** and the relatively larger profile of the stiffener **280**. The relatively low elastic modulus of the adhesive **282** allows the adhesive **282** to stretch to accommodate the shear force generated by the changes between the profiles of the stiffener **280** and the motor **234**. A relatively higher modulus adhesive **282** (not shown) may not deform in shear to the extent of a lower modulus adhesive, and may thereby reduce the amount of expansion of the motor **234** to reduce the stroke increase provided by the stiffener **280**. Performance advantages can thereby be achieved by balancing the elastic modulus of the adhesive **282** and the elastic modulus of the stiffener **280**. The elastic modulus of the adhesive **282** can be approximately 2000 times lower than the modulus of the material that forms the stiffener **280**.

During actuation, the motor **234** may twist about the longitudinal axis of the motor **234** during actuation of the motor **234**. Also, the stiffener **280** may also be caused to twist about the longitudinal axis of the stiffener **280** by the actuation of the motor **234**. However, the presence of the stiffener **280** can limit the degree of twisting of the motor **234** about the longitudinal axis of the motor **234**. In some embodiments, because the twisting can be caused by the resistance provided by the flexure **212**, as discussed above, the presence of the stiffener **280** on the side of the motor **234** opposite the flexure **212** can reverse the direction of twist as compared to an embodiment without the stiffener **280**. As such, the presence and configuration (e.g., shape, elastic modulus) of the stiffener **280** can be balanced with the mechanics of the flexure **212** to minimize twisting, maximize longitudinal stroke of the motor **234**, and/or reverse the twisting profile of the motor **234**.

FIGS. **22-24** are illustrations of a flexure **312** having a DSA structure **314** with an asymmetric stiffener **380** in accordance with another embodiment of this disclosure. The flexure **312** is part of a DSA structure **314** that can be similar to that of DSA structure **214** described above or other DSA structure referenced herein except where noted. Features of flexure **312** that are the same or similar to those of other flexures are indicated by similar reference numbers. The gimbal **324** is shown with the motor **334** in a neutral or unactuated state in FIG. **22**, a contracted actuated state in FIG. **23**, and an expanded actuated state in FIG. **24**. Stiffener **380** can be attached to motor **334** by adhesive **382**. As shown, the stiffener **380** has a central section **387** and a pair of arms comprising a first arm **388** and a second arm **389**. A first arm **388** extends laterally away from the central section **387** in a first direction (i.e. to the right and orthogonal relative to the longitudinal axis of the gimbal **324**, parallel relative to the longitudinal axis of the motor **334**). A second arm **389** extends laterally away from the central section **387** in a second direction (i.e. to the right and orthogonal relative to the longitudinal axis of the gimbal **324**, parallel relative to the longitudinal axis of the motor **334**) opposite the first direction.

The stiffener **380** is asymmetric about both of the length and width axes of the central section **387**. For example, the first arm **388** extends along a first longitudinal axis, the second arm **389** extends along a second longitudinal axis, and the first longitudinal axis is offset from the second longitudinal axis. As shown, the first arm **388** is proximal relative to the second arm **389**. The offset relationship of the first arm **388** and the second arm **389** can mirror the offset relationship of the struts **356**. It is noted that while strut **356** is shown in FIGS. **22-24**, the configuration of the struts **356** can be the same as the struts **56** shown in FIG. **4B**. For example, a first strut **356** on the right side of the flexure **312** can be proximal of the second strut **356** on the left side of the flexure **312** while the first arm **388** on the right side of the stiffener **380** is proximal of the second arm **389** on the left side of the stiffener **380**. The stiffener **380** can be between the struts **356** (e.g., from a plan view perspective or along a plane that is coplanar with the flexure **312**). The offset profile of the first arm **388** and the second arm **389** corresponding to the offset profile of the struts **356** allows the first arm **388** to mechanically counteract the proximal strut **356** and the second arm **389** to mechanically counteract the distal strut **356**. In some embodiments, the width of the first arm **388** is different (e.g., less) than the width of the second arm **389**. In other embodiments (not shown), the stiffener has other asymmetrical shapes or is symmetric about the central section **387**.

The stiffener **380** can provide sufficient stiffness to equally balance and counteract the bending of the motor **334** as the motor **334** is expanded (e.g., as shown in FIG. **23**) and contracted (e.g., as shown in FIG. **24**). This action is provided at least in part because of the relatively less amount of material, and therefore less stiffness (e.g., compared to embodiments with stiffeners such as 280 described above). The presence and configuration (e.g., shape, elastic modulus, alignment with struts **356**) of the stiffener **380** can be balanced with the mechanics of the flexure **312** to minimize bending of the motor **334** and flexure **312**, maximize longitudinal stroke of the motor **334**, and/or reverse the bending profile of the motor **334**. In one embodiment, the stiffener **380** provides a stroke increase of approximately 30% over similar embodiments of the flexure with no stiffener. Stiffener **380** also provides less twist along the long axis of the motor **334** during actuation of the motor. Minimizing twist of the motor **334** can reduce excitation of flexure resonance modes by reducing motion of the flexure arms and traces.

Connectors **345** electrically and mechanically connect the motor **334** to the flexure **312**. More specifically, the connectors **345** make electrical connections between traces of the flexure **312** and terminals of the motor **334**. The connectors **345** can further attach the motor **334** to the spring arms **352**. The slider **332** is mounted to a slider mounting of the tongue **333**. The slider mounting can be a surface of the tongue **333** to which the slider **332** can be attached, such as with an adhesive such as epoxy. Rotation of the tongue **333** by actuation of the motor **334** rotates the slider mounting, and thereby the slider **332**, about a tracking axis.

FIG. **25** is detailed isometric view of the stainless steel side of the distal end of a flexure **412** having a DSA structure **414** with a stiffener **480** in accordance with another embodiment of this disclosure. FIG. **26** is a distal end view of the flexure **412** shown in FIG. **25**. FIG. **27** is an illustration of the flexure **412** shown in FIG. **25** when the motor **434** is actuated into an expanded state. The flexure **412** is part of a DSA structure **414** that can be similar to that of DSA structure **214** described above or other DSA structure referenced herein except where noted. Features of flexure **412** that are the same or similar to those of other flexures are indicated by similar reference numbers. As shown, the stiffener **480** has a center section **487** and a pair of opposite side sections **488** and **489**. Each of the side sections **488** and **489** are separated from the center section **487** by openings **491**. Each opening **491** is a void in the stiffener **480** that extends from a first side of the stiffener **480** to a second side of the stiffener **480** opposite the first side. Each opening **491** is entirely bounded along the plane of the stiffener is lateral (i.e. left and right) as well as proximal and distal directions. Alternatively, an opening **491** can be open on any of the lateral, distal, and/or proximal sides.

The stiffener **480** is attached to the motor **434** by a plurality of adhesive layers **482_1-482_2**. As shown, the plurality of adhesive layers **482_1-482_2** are separate and do not contact one another. Each of the adhesive layers **482_1-482_2** can be a different type of adhesive such that each layer has a different elastic modulus. In the illustrated embodiment, for example, the center section **487** of the stiffener **480** is attached to the motor **434** by a first adhesive **482_1** and the side sections **488** and **489** are attached by a second adhesive **482_2**. The first adhesive **482_1** can have a relatively low elastic modulus while the second adhesive **482_2** can have a relatively high elastic modulus such that the elastic modulus of the first adhesive **482_1** is lower than the elastic modulus of the second adhesive **482_2**. The first adhesive **482_1** can, for example, have the same properties as the adhesive **282** described above (e.g., by having an elastic modulus of around 100 MPa). The second adhesive **482_2** can, for example, have an elastic modulus of about 2800 MPa. Other stiffeners, and other adhesives including adhesives having other elastic moduli, can be used and are within the scope of this disclosure. Since the second adhesive **482_2** is generally confined to the lateral sides of the motor **434**, the higher elastic modulus of the second adhesive **482_2** resists expansion and contraction over a relatively limited length. As shown in FIG. **27**, the second adhesive **482_2**, having a relatively high modulus, does not shear to the degree that a relatively lower elastic modulus adhesive would (e.g., as shown in FIG. **20**). The second adhesive **482_2** remains relatively rigid and can cause an increase in bending of the motor **434** toward the stiffener **480** when the motor **434** expands. The amount of stretch from the motor **434** is thereby enhanced, increasing the stroke (e.g., by amounts of 100% or more) over the stroke of similar gimbals without the stiffener **480**.

Connectors **445** electrically and mechanically connect the motor **434** to the flexure **412**. More specifically, the connectors **445** make electrical connections between traces of the flexure **412** and terminals of the motor **434**. The connectors **445** can further attach the motor **434** to the spring arms **452**. The slider **432** is mounted to a slider mounting of the tongue **433**. The slider mounting can be a surface of the tongue **433** to which the slider **432** can be attached, such as with an adhesive such as epoxy. Rotation of the tongue **433** by actuation of the motor **434** rotates the slider mounting, and thereby the slider **432**, about a tracking axis.

FIG. **28** is detailed isometric view of the stainless steel side of the distal end of a flexure **512** having a DSA structure **514** with a stiffener **580** mounted on the motor **534**. FIG. **29** is a detailed side view of the distal end of the flexure **512** shown in FIG. **28**. The flexure **512** is part of a DSA structure **514** that can be similar to that of DSA structure **214** described above or other DSA structure referenced herein except where noted. Features of flexure **512** that are the same or similar to those of other flexures are indicated by similar reference numbers. The stiffener **580** is similar to the stiffener **480** described above but the stiffener **580** has multiple thicknesses. Specifically, the stiffener **580** has reduced thickness portions **593** at the distal and proximal ends of the center section **587** and opposite side sections **588** and **589**. For example, the distal and proximal ends of the stiffener **580** are thinner than the middle of the stiffener **580**. In this way, the reduced thickness portions **593** extend along a perimeter of the stiffener **580**. As shown, the sections of the stiffener **580** that bridge between the center section **587** and the side sections **588** and **589** have a smaller thickness with respect to the respective middles of the center section **587** and the side sections **588** and **589**. Multiple adhesives **582_1** and **582_2** are attached to the motor **534** and the stiffener **580**. The adhesives **582_1** and **582_2** can be the same as or similar to the adhesives **482_1** and **482_2** described above. The adhesive **582_1** is underneath the center section **587** and can have a lower elastic modulus than the adhesives **582_2** that are underneath the side sections **588** and **589**. Other embodiments (not shown) can have more than two sections each a having a different thickness (e.g., three sections having different thicknesses) and/or other configurations of different thicknesses.

Connectors **545** electrically and mechanically connect the motor **534** to the flexure **512**. More specifically, the connectors **545** make electrical connections between traces of the flexure **512** and terminals of the motor **534**. The connectors **545** can further attach the motor **534** to the spring arms **552**. The slider **532** is mounted to a slider mounting of the tongue **533**. The slider mounting can be a surface of the tongue **533** to which the slider **532** can be attached, such as with an adhesive such as epoxy. Rotation of the tongue **533** by actuation of the motor **534** rotates the slider mounting, and thereby the slider **532**, about a tracking axis.

FIG. **30** is detailed isometric view of the stainless steel side of the distal end of a flexure **612** having a DSA structure **614** with an asymmetric stiffener **680** attached to the motor **634** with multiple adhesives **682_1** and **682_2**. The flexure **612** is part of a DSA structure **614** that can be similar to that of DSA structure **214** described above or other DSA structure referenced herein except where noted. Features of flexure **612** that are the same or similar to those of other flexures are indicated by similar reference numbers. As shown, each side section **688** and **689** of the stiffener **680** forms an "L" shape arm which includes a connecting section **693** that extends laterally from the center section **687** and a longitudinal section **694** that extends longitudinally (e.g., proximally or distally) from the end of the connecting section **693**. As shown, the connecting sections **693** extend orthogonal with respect to the center section **687** and the longitudinal sections **694**. Only a single connecting section **693** of the stiffener **680** extend between the center section **687** and each longitudinal section **694**. As shown, a first one of the connecting sections **693** is proximal with respect to a second one of the connecting sections **693**. The offset relationship of the connecting sections **693** can mirror the offset relationship of the struts **656**. It is noted that while strut **656** is shown in FIG. **30**, the configuration of the struts **656** can be the same as the struts **56** shown in FIG. 4B. For example, a first strut **656** on the right side of the flexure **612** can be proximal of the second strut **656** on the left side of the flexure **612** while a first one of the connecting sections **693** on the right side of the stiffener **680** is proximal of a second one of the connecting sections **693** on the left side of the stiffener **680**. The stiffener **680** can be between the struts **656** (e.g., from a plan view perspective or along a plane that is coplanar with the flexure **612**). The offset profile of the connecting sections **693** corresponding to the offset profile of the struts **656** allows the connecting sections **693** to respectively mechanically counteract the struts **656**. The asymmetric configuration of the stiffener **680** can reduce twist of the motor **634** during expansion and contraction. Portions of center section **687** and longitudinal sections **694**, and connecting sections **693**, extend beyond the distal and proximal edges of the motor **634** in the illustrated embodiment. In various other embodiments (not shown) the stiffener **680** entirely overlays the top surface of the motor **634** and extends beyond the distal and/or proximal edges of the motor **634**. In still other embodiments (not shown) the stiffener **680** has still other shapes and sizes with respect to the shape and size of the motor **634**.

Connectors **645** electrically and mechanically connect the motor **634** to the flexure **612**. More specifically, the connectors **645** make electrical connections between traces of the flexure **612** and terminals of the motor **634**. The connectors **645** can further attach the motor **634** to the spring arms **652**. The slider **632** is mounted to a slider mounting of the tongue **633**. The slider mounting can be a surface of the tongue **633** to which the slider **632** can be attached, such as with an adhesive such as epoxy. Rotation of the tongue **633** by actuation of the motor **634** rotates the slider mounting, and thereby the slider **632**, about a tracking axis.

FIG. **31** is an illustration of a flexure **712** having a DSA structure **714** with an asymmetric stiffener **780** in accordance with another embodiment of this disclosure. The flexure **712** is part of a DSA structure **714** that can be similar to that of DSA structure **214** described above or other DSA structure referenced herein except where noted. Features of flexure **712** that are the same or similar to those of other flexures are indicated by similar reference numbers. As shown, the stiffener **780** has a center section **787** and oppositely extending first arm **788** and second arm **789**. The first arm **788** on one side of the stiffener **780** has a smaller width (i.e., in a direction of the longitudinal axis of the flexure **712**) than the width of the second arm **789** on the other side of the stiffener **780**. The first arm **788** can have a width of about one-half the width of the second arm **789**. It will be understood that the relative widths of the first and second arms **788** and **789** can be reversed such that second arm **789** can have a smaller width than the first arm **788**. Similar embodiments can have other relative dimensions. Alternatively, the first and second arms **788** and **789** can have the same widths. It is also noted that the first arm **788** is proximal with respect to the second arm **789**. The asymmetry of the stiffener **780** enables the DSA structure **714** to have different bending characteristics on its opposite transverse sides (i.e., with respect to a longitudinal axis). The offset relationship of the first and second arms **788** and **789** can mirror the offset relationship of the struts **756**. It is noted that while strut **756** is shown in FIGS. **31-32**C, the configuration of the struts **756** can be the same as the struts **56** shown in FIG. **4**B. For example, a first strut **756** on the right side of the flexure **712** can be proximal of the second strut **756** on the left side of the flexure **712** while a first arm **788** on the right side of the stiffener **780** is proximal of a second arm **789** on the left side of the stiffener **780**. The stiffener **780** can be between the struts **756** (e.g., from a plan view perspective or along a plane that is coplanar with the flexure **712**). The offset profile of the first and second arms **788** and **789** corresponding to the offset profile of the struts **756** allows the first and second arms **788** and **789** to respectively mechanically counteract the struts **756**.

FIGS. **32**A and **32**B are illustrations of the flexure **712** shown in FIG. **31** when the motor **734** is actuated into contracted and expanded states, respectively. As shown, because of the relatively lower stiffness provided by the first arm **788** due to the second arm **789** being wider, the side of the flexure **712** with the first arm **788** bends more than the side of the flexure **712** with the second arm **789**. The amount of side-to-side differential bending is related to the difference in stiffness between the first and second arms **788** and **789**. The rotational center of the DSA structure **724** can be changed and tuned by the stiffener **780** by adjusting various variables, including the relative widths or thicknesses, and therefore the relative stiffnesses, of the first and second arms **788** and **789**.

Connectors **745** electrically and mechanically connect the motor **734** to the flexure **712**. More specifically, the connectors **745** make electrical connections between traces of the flexure **712** and terminals of the motor **734**. The connectors **745** can further attach the motor **734** to the spring arms **752**. The slider **732** is mounted to a slider mounting of the tongue **733**. The slider mounting can be a surface of the tongue **733** to which the slider **732** can be attached, such as with an adhesive such as epoxy. Rotation of the tongue **733** by actuation of the motor **734** rotates the slider mounting, and thereby the slider **732**, about a tracking axis.

Flexures with DSA structures having stiffeners can provide important advantages. The stiffener changes the deformed shape of the PZT motor when the motor expands and contracts during operation. This shape change can be tailored to increase the stroke amount of the actuator assembly, therefore achieving more stroke for the same input voltage to the motor. Alternatively, the same stroke can be maintained but with a lower voltage as compared to embodiments without a stiffener. Another advantage of the stiffener is that twist or asymmetric bending of the motor can be minimized by design of the stiffener. Increasing stroke performance is an advantage in particular for co-located dual stage actuators since high stroke is difficult to achieve due to the inherent low mechanical advantage when the motor is located close to the slider that the motor is moving. Due to low stroke, gimbal actuator designs may require the use of more expensive multi-layer PZT motors as opposed to simple single layer and lower cost motors. By increasing the stroke performance, stiffeners can reduce the number of PZT motor layers needed for a design and even allow for the use of single layer PZT motors to achieve stroke targets.

In some embodiments, the center of rotation of the motor, tongue, and/or slider can be adjusted by tailoring how the motor bends during actuation with a stiffener. For example, the center of rotation can be located to extend through the dimple load point (e.g., where the dimple contacts the stiffener). If the actuator's center of rotation is not located directly at the dimple load point, then resonance performance may be reduced. The tailored stiffener designs, discussed above, can be used to move the center of rotation by changing how the motor deforms.

The stiffener also provides a protective covering over the motor, which may otherwise be fragile. For example, the stiffener provides a point upon which the dimple can press, wherein equivalent pressure from the dimple directly on the motor may damage the motor. The stiffener can protect the motor surface from mechanical wear due to the dimple and shock loads at the dimple point. Shock loads will be distributed by the stiffener. The stiffener can also provide electrical insulation of the motor. For example, the loadbeam can serve as an electrical ground in some embodiments, and in such case the motor can be insulated from electrical connection through the dimple of the loadbeam by the stiffener. If the stiffener is formed from an electrically conductive metal, then the adhesive layer between the stiffener and the motor can serve as electrical insulation.

While the use of a stiffener has been described in association with various gimbaled flexure embodiments, it is noted that a stiffener can be used with any flexure referenced herein.

For example, in the embodiment of FIG. **9-16**C_2, a stiffener can be positioned on the motor **134** while the slider **132** can be attached to the stiffener (e.g., with an epoxy adhesive) and/or the slider **132** can be attached to the motor **134** at a location not covered by the stiffener.

Although the present invention has been described with reference to preferred embodiments, those skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention. For example, although described in connection with certain co-located DSA structures, stiffeners and associated features described herein can be used in connection with motors on other DSA structures, including other co-located DSA structures.

The following is claimed:

1. A suspension having a gimbaled dual stage actuation structure, comprising:

a flexure comprising a gimbal, the gimbal comprising at least one spring arm and a tongue connected to the at least one spring arm;

a piezoelectric motor mounted on the at least one spring arm of the gimbal; and

a stiffener mounted on the motor with an adhesive, wherein the adhesive comprises a layer of adhesive that is located between the motor and the stiffener.

2. The suspension of claim **1**, wherein the stiffener is stiffer than a portion of the gimbal and the motor is mounted on the portion of the gimbal.

3. The suspension of claim **1**, wherein the stiffener limits the degree of bending of the motor during activation of the motor.

4. The suspension of claim **1**, wherein the stiffener comprises a layer of metal.

5. The suspension of claim **1**, wherein the stiffener comprises a layer of polymer.

6. The suspension of claim **1**, wherein the gimbal comprises a top side, a bottom side opposite the top side, and a slider mounting, wherein the motor is mounted on the top side of the gimbal while the slider mounting is located on the bottom side of the gimbal.

7. The suspension of claim **1**, wherein the stiffener has a first thickness along a first portion of the stiffener and a second thickness along a second portion of the stiffener, the second thickness less than the first thickness, each of the first and second thicknesses measured from a first side of the stiffener to a second side of the stiffener.

8. The suspension of claim **1**, wherein the stiffener comprises one or more voids, each void extending from a first side of the stiffener to a second side of the stiffener opposite the first side.

9. The suspension of claim **1**, wherein the stiffener comprises a left lateral side and a right lateral side, the left lateral side and the right lateral side divided by a midline along the center of the stiffener, wherein the left lateral side is asymmetric with respect to the right lateral side.

10. The suspension of claim **1**, wherein the stiffener comprises a center section, a first arm extending laterally away from the center section in a first direction, and a second arm extending laterally away from the center section in a second direction.

11. The suspension of claim **10**, wherein the first arm is distally offset with respect to the second arm.

12. The suspension of claim **1**, wherein the at least one spring arm comprises a pair of spring arms on which the motor is mounted, and the gimbal further comprises a tongue located between the spring arms.

13. The suspension of claim **12**, wherein the tongue comprises a slider mounting.

14. A suspension having a gimbaled dual stage actuation structure, comprising:

a flexure comprising a gimbal;

a piezoelectric motor mounted on the gimbal; and

a stiffener mounted on the motor, the stiffener attached to the motor with an adhesive that is located between the motor and the stiffener, and wherein the stiffener is stiffer than a portion of the gimbal and the motor is mounted on the portion of the gimbal.

15. The suspension of claim **14**, wherein the stiffener comprises a layer of metal.

16. The suspension of claim **14**, wherein the stiffener comprises a layer of polymer.

17. A suspension having a gimbaled dual stage actuation structure, comprising:

a flexure comprising a gimbal, the gimbal comprising a pair of spring arms and a tongue located between the spring arms;

a piezoelectric motor mounted on the pair of spring arms; and

a stiffener mounted on the motor, the stiffener attached to the motor with an adhesive, wherein the adhesive comprises a layer of adhesive that is located between the motor and the stiffener.

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